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MINIMUM FLOW OF NORTH CAROLINA STREAMS[1]

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North Carolina's pioneer period is now passed; the period of exploitation is almost over. An urban population, industrially minded, has replaced our predecessors of simple wants. Today municipalities and industries are reaching out for larger, better and less expensive water supplies, on the one hand, and seeking economically to dispose of wastes on the other. Most of us necessarily and preferably look to streams as our source of water supply. Economy requires that we shall look to them also for assistance with our wastes. In North Carolina today as elsewhere, water courses have become an integral part of our water purification and waste treatment systems. Design must be proportioned to the size and characteristics of the watershed. Operation must be adjusted continually to follow fluctuations in stream flow and quality of water. Storage may or may not be necessary depending on volume and characteristics of flow.

Water in general, and our water courses in particular, have come to the forefront as among the most important and valuable of our natural resources. Water today has value, costs money. But yesterday it was disregarded; today it is only beginning to receive attention; but tomorrow it will be the subject of keen competition.

[1] Presented before the North Carolina Section meeting, November 3, 1931.

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This decade marks the beginning of a period in which we shall compete for water and water rights. There is and will be competition both as between ownership and usage. As surely as water continues to flow; as surely as the state and nation continue their forward march of progress, this competition will increase in intensity.

Unfortunately, perhaps, for our utilitarian usage of streams, they are very capricious. Subject to the whims of nature their flow is ever changing. They are of one size today; another tomorrow. Swelled to tremendous torrents by floods, they may be reduced to trickles by droughts. The flow of a stream in flood may in a day deliver water sufficient to meet the days needs of 1,000,000 people, but on another day when the countryside is parched, be sufficient for only 1,000. The regimen of a stream is incredibly great; its characteristics incredibly complicated. Philosophy proved inadequate. We have had to develop stream gaging to measure stream regimen; to develop their characteristics. Gaging of North Carolina streams has hardly more than begun. Yet the longer records span three drought periods, and sufficient streams were gaged in 1925–26 and 1930–31 to permit characteristics to be roughly developed. We can with some relative accuracy compare the drought periods of 1894–95, 1925–26 and 1930–31. We can say with some assurance that, within the span of our records, 1930 has been the driest and 1906 the least dry of record when the state as a whole is considered. We can compare the range of watershed yield in the mountains with that in the Piedmont. We can see that the yield of similar sized areas in the same region may differ greatly. These and other things can be learned from records of stream flow. The information to be derived is of practical application in our problems. A stream flow record is the avenue to understanding on the part of the water works engineer. This study constitutes a look-in on North Carolina stream flow under drought conditions. Our general objective is to learn something of minimum flow.

OBJECTIVES

In gaining the larger objective, various approaches have been made, and different aspects reviewed to some extent. The dependence of stream flow on many inter-dependent and inter-related functions of nature has been emphasized. Variation in stream flow as the natural rather than the unusual condition has been stressed, and it is pointed out that variations in value of minimum yields are to

be expected. It is pointed out that while droughts of serious proportions nearly always extend over large areas, different sections will be affected unequally. In this connection, 1930 conditions in North Carolina are cited. Reference is made to the frequency of drought occurrence. Newly compiled data relating to the 1925–26 and 1930 droughts are included and used to emphasize the great differences in yield observed. One or two extreme conditions are described in emphasis of various points. It is pointed out that differences in characteristics are of both a regional and an inter-regional nature. Finally, we shall attempt to size up the extent of our present understanding of the phenomenon of drought stream flow. Throughout, emphasis is placed on the characteristics and economic implications, this study in no sense being a presentation of records. Further, it is pointed out that present observational studies should be greatly expanded and that both individuals and agencies should exert themselves to increase the number of analytical contributions in interpretation of the body of data as it may be compiled.

ACKNOWLEDGMENTS

This paper is to be considered as a contribution from the Water Resources and Engineering Division of the Department of Conservation and Development. In its preparation, James P. Clawson, Assistant Engineer, has assisted extensively in the handling of technical data. Others of the Division personnel have assisted in their respective capacities. Acknowledgment is made to the Chief Engineer for his constructive criticism.

Obviously, such a paper as this is possible of preparation only after observational data have been collected over a long period of years. Stream gaging has been under the joint direction of the District Engineer of the United States Geological Survey and the Chief Engineer of the Department of Conservation and Development, and it is to them together with the administrative officials of the two agencies that we are most greatly indebted. Individuals, companies, municipalities, and other governmental agencies have assisted from time to time by the contribution of funds and otherwise giving support to the work.

AVAILABILITY OF DATA

Through the coöperative efforts of the United States Geological Survey and the Department of Conservation and Development,

TABLE 1

Condensed report of stream gaging operations in North Carolina, January 1, 1931

Total years of records available for entire State, 824

RIVER BASIN	ACTIVE STATIONS IN EACH BASIN	ACTIVE STATIONS EQUIPPED WITH RECORDERS	DISCONTINUED STATIONS	NUMBER OF RECORDS AVAILABLE*	AVERAGE LENGTH OF RECORD (YEARS)	AVERAGE DRAINAGE AREA ABOVE STATION† (SQUARE MILES)	LONGEST RECORD, EACH BASIN: Length (years)	LONGEST RECORD, EACH BASIN: Gaging station
Roanoke	5	5	4	9	5.5	2,470	20	Roanoke River at Old Gaston
Tar	2	0	1	3	6.5	1,050	7	Fishing Creek at Enfield
Neuse	12	5	4	16	3.5	324	6	Flat River near Bahama
Cape Fear	17	15	3	20	5.0	790	31‡	Cape Fear at Fayetteville
Yadkin	7	5	8	15	7.5	2,340	32	Yadkin at Salisbury
Catawba	5	2	12	15	2.5	255	9	Linville at Branch
Broad	3	3	5	8	3.5	188	6	Second Broad at Cliffside; Broad near Boiling Sprgs.
Savannah	0	0	0	0				
New	2	1	3	5	5.5	231	8	S. Fk. New at Crumpler; N. Fk. New at Crumpler
Watauga	0	0	0	0				
French Broad	12	8	14	26	6.0	177	34‡	French Broad at Asheville
L. Tennessee	9	4	10	19	8.5	253	35	L. Tennessee at Judson
Hiwassee	3	1	3	6	1.4	176	35	Hiwassee at Murphy
Total	77	49	67	142*			223	
Average	6	4	5	11	6	750	20	

* In general records have not been counted as being available for stations in operation less than a year.

† Values given are approximately correct. Areas not determined as yet for some of the new stations.

‡ Record not continuous from date of first operation.

stream flow records are available to the extent described in table 1, giving a condensed report of stream gaging operations in the State as of January 1, 1931. As of that date, 824 years of record were available involving 144 stations, providing an average length of record of six years, relating to drainage areas having an average size of 750 square miles. Rainfall records to a relatively satisfactory extent are available through the United States Weather Bureau. Recently the Department of Conservation and Development, in cooperation with the U. S. Geological Survey, installed instrumental equipment on an abandoned well in Chapel Hill for the purpose of observing fluctuations in ground water level. Information on ground water phenomena[3] has become available incidentally during the past ten years through the increased use of stream gaging recorders which record accurately and to the desired degree of magnification every change in stream stage.

Stream flow records are not satisfactorily available with respect to length of individual records or average length, number of records available, records for small streams, their distribution in general, and in particular, and with respect to certain areas. The program is in need of expansion as is well known by this Association. Rainfall stations should be increased in number and particularly to include additional recording gages to provide intensity information. Ground water observations through the medium of wells should be expanded to include selected points over the State. This latter endeavor is one in which the individual members can assist by personal observations.

UNITS AND CONCEPT

The hydrographer and the governmental hydrographic agencies customarily measure stream flow in terms of cubic-feet and in terms of yield per square mile it becomes second-feet per square mile. Men in the water works field, particularly those concerned with plant

[3] Diurnal fluctuation of stream flow due to evaporation and transpiration likely was first observed years ago, but it is only since the recording gage has been in use that we have been able to observe satisfactorily the nature and range of the phenomenon, and to undertake analytically its study. E. D. Burchard, Engineer of the U. S. Geological Survey for the North Carolina District, is thought to have been first in pointing out the practical proportions and significance of the phenomenon. As a typical case of such fluctuation see Journal of North Carolina Section, American Water Works Association, 1928; fig. 2 on page 26, relating to South Fork of Mills River near Asheville.

operations, are accustomed to deal with water flows in terms of millions of gallons daily (m.g.d.) This results in making it difficult to present a discussion of this nature, but water is water regardless of the unit of measurement and we have the relationship:

1 sec.-ft. = 0.646 m.g.d. = 646,317 gallons daily
1 m.g.d. = 1.549 sec.-ft.

The basic records on which the study are based are compiled in terms of second-feet, but in order that the real magnitude of values may be quickly comprehended by men from both fields, an effort has been made to state some of the tables in both units.

In these as in most other measurements, the time element is involved. Stream flow may be reported in terms of the average rate of flow on an hourly, daily, weekly, monthly, and on an annual basis. Also, for any other period of record appropriate. Weekly discharge for a given stream and for a given week may be defined as the average rate of flow during the week in question. In general, it is the discharge averaged over a seven-day period. Similarly, daily discharge is that averaged over 24-hour periods; monthly, that over 28, 30, and 31-day periods; and annual, that over 365-day periods.

Practically all of the stream flow quantities referred to in the discussion and also in the tables are given on a per square mile basis, whether reported in second-feet or million gallons daily. Weekly discharge per square mile has been chosen as the most satisfactory unit for comparative use and in general discussion. Its choice was in preference to annual, monthly, daily, or momentary discharge because the period of duration considered should in general be short, and because due to the nature of stream gaging operations, minimum flow values in this unit may be considered more reliable,[4] considering

[4] Detailed reasoning underlying choice of the weekly period is omitted as being beside the point. Stream flow records in general are accurate and are not to be questioned even as to daily and momentary flows. However, it was not possible in the beginning of stream gaging in this state to apply standards of accuracy now in effect. For instance, reliable recording apparatus has only been in use during the past ten years. Moreover, as a general proposition, minimum flows are relatively difficult of ascertainment and artificial regulation of flow by small reservoirs on the watersheds, ordinarily having no appreciable effect on the flow of the stream being measured, may in times of minimum flow cause considerable fluctuation affecting the daily discharge but in all probability, not the weekly values.

our whole body of data, than can those in terms of daily or momentary discharge. Obviously, during the period of minimum weekly flow, there will be days when the flow is less than that represented by the weekly figure, and hours when it will be less still. Due account of these relationships will be taken by any engineer in dealing with a specific problem. Little attention is paid in this study to the values of actual flow in the case of the streams discussed. Individually, streams referred to are of no consequence except as they are an index of stream characteristics in their respective localities.

STREAM FLOW DEPENDENCE

Stream flow has been termed residual rainfall; is in a sense surplus rainfall with respect to nature's demands; and a stream may be likened unto a beggar seeking alms along the street. First and foremost, stream flow is dependent upon precipitation and its share is dependent upon both the magnitude and the intensity with which the downpour occurs. Subsequently, its further share is dependent somewhat on both the nature of the top soil and the underlying formation. Here, vegetation has the first choice and the amount of water withdrawn from the soil and consequently removed beyond the reach of the stream is enormous. Further, the amount of water which will reach the stream is dependent to a very considerable extent on prevailing temperatures. Freezing temperatures are a considerable factor in northern regions, but bother us but little in North Carolina. Instead it is the higher temperature range in which evaporation and transpiration are effective with which we are concerned.

It is only since the beginning of installation of highly sensitive accurate water-stage recorders about ten years ago that we have come to appreciate the very great regulating affect that temperature has on the yield of drainage areas of 25 square miles and less under drought conditions. The upper limit of size affected has not yet been determined and it is to be assumed that the size is dependent to a considerable extent on character of soil and vegetation. It is quite well established, however, that for streams of 10 to 15 square miles and less the drought hydrograph essentially has the appearance of a sine wave, depressed flow frequently being 30 percent or more less than the peak flow occurring daily. This phenomenon among others relating to drought flows, is not clearly understood, but it is known that evaporation and transpiration are the agencies effective in causing the decreased flow. It has recently been referred to by

John C. Hoyt[5] of the United States Geological Survey as the consumptive draft of vegetation.

DROUGHT OCCURRENCES

Our ordinary conception is that a drought condition exists when we experience rainfall and stream flow markedly below normal; sufficiently so as to call attention to itself and to cause general inconvenience. Students of rainfall and stream flow also know that it is possible to have a drought in either rainfall or stream flow alone. We may cite 1930 as a year in which we experienced a marked rainfall drought, but in which stream flow held up proportionately well except in a few local areas. During the present year, generally speaking, stream flow has been more deficient than rainfall. A specific definition of a drought, comprehensive in all respects, would be extremely difficult of formulation, and perhaps then, would not be of any great value. However, a little later during the course of this discussion, it is proposed for practical working purposes to formulate a partial definition of a stream flow drought.

In considering drought occurrences, questions of frequency, together with questions as to magnitude both actual and relative, must be given some consideration. It has not been possible to include statistically correct studies of these phases of drought occurrence in this discussion. However, the records speak for themselves to some extent, and as tables 2 and 3 we are presenting from seven of the longer stream flow records, minimum weekly discharge data for as many of the larger North Carolina streams. For each year of record, table 2 presents in terms of second-feet per square mile, the lowest value of weekly flow occurring each year. In table 3, we find in the case of each record this same quantity reported in terms of discharge as the percent of the mean discharge of each respective record. As an illustration, the lowest weekly flow of the Hiwassee River during the year 1898 was 0.820 second-feet per square mile. This was 34 percent of the mean annual value, which is 2.41 second-feet per square mile. In other words, in table 3, for each record, the low weekly flow occurring each year is stated in terms of percent of average flow, which we quite often (incorrectly) refer to as normal flow.

[5] John C. Hoyt, Hydraulic Engineer, U. S. Geological Survey; Civil Engineering, October 1931.

TABLE 2

Minimum weekly discharge of larger North Carolina streams

YEAR	HIWASSEE AT MURPHY	TUCKASEGEE AT BRYSON	FRENCH BROAD AT ASHEVILLE	YADKIN AT SALISBURY	ROANOKE AT OLD GASTON	CAPE FEAR AT FAYETTEVILLE	FISHING CREEK NEAR ENFIELD
Drainage area, square miles......	410	673	949	3,400	8,350	4,290	462
	Discharge in second-feet per square mile						
Mean annual........	2.41	2.46	2.38	1.47	0.981	1.15	1.21
1889						0.273	
1890						0.211	
1891						0.327	
1892						0.116	
1893						0.140	
1894						0.162	
1895						0.115	
1896			0.694	0.360		0.190	
1897			0.622	0.350		0.080	
1898	0.820	0.812	0.757	0.452		0.165	
1899	0.710	0.446	0.782	0.468		0.162	
1900	0.676	0.816	0.766	0.477		0.098	
1901	1.05	0.964	1.88	0.790		0.298	
1902	0.495	0.640		0.526		0.100	
1903	0.510	0.579		0.550		0.121	
1904	0.390	0.514	0.305	0.350		0.238	
1905	0.630	0.713	0.832	0.521		0.190	
1906	(1.38)	(1.52)	(1.69)	0.758		0.246	
1907	1.122	0.937	0.502	0.560		0.127	
1908	0.802	0.776	1.20	0.741		(0.330)	
1909	0.914	0.970	1.24	0.706		0.189	
1910	0.732	0.794	1.07	0.539		0.223	
1911	0.646	0.804	0.669	0.359		0.172	
1912	0.849	0.944	1.09	0.534	0.181	0.150	
1913	0.568	0.811	0.983	0.592	0.246	0.303	
1914	0.490	0.579	0.706	0.420	0.114	0.153	
1915	0.604	1.145	1.28	0.610	0.299	0.191	
1916	0.974	0.961	1.05	(0.821)	0.214	0.173	
1917	0.980	0.975	0.864	0.542	0.129		
1918	0.746	0.858	0.750	0.442	0.112		
1919	0.578	1.11	0.797	0.615	0.181		0.281
1920	0.708	1.01	1.07	0.615	0.172		0.115
1921	0.608	0.900	0.778	0.442	0.110		0.054
1922	0.663	0.659	0.680	0.521	0.131		0.102
1923	0.619	0.691	0.806	0.453	0.309		0.097

TABLE 2—*Concluded*

YEAR	HIWASSEE AT MURPHY	TUCKASEGEE AT BRYSON	FRENCH BROAD AT ASHEVILLE	YADKIN AT SALISBURY	ROANOKE AT OLD GASTON	CAPE FEAR AT FAYETTEVILLE	FISHING CREEK NEAR ENFIELD
Drainage area, square miles......	410	673	949	3,400	8,350	4,290	462
Discharge in second-feet per square mile							
Mean annual........	2.41	2.46	2.38	1.47	0.981	1.15	1.21
1924	0.395	0.632	0.790	0.521	0.274		(**0.302**)
1925	**0.268**	**0.300***	**0.274**	**0.262**	0.178		0.177
1926	0.317	0.662	0.439	0.288	0.136		0.095
1927	0.600	0.744	0.592	0.319	0.243		0.110
1928	1.105	1.24	1.28		**0.275**		0.207
1929	0.997	1.05	0.907		(0.389)	0.312	0.290
1930	0.436	0.576	0.479		**0.069**	**0.038**†	0.091
Maximum....	1.380	1.52	1.69	0.821	0.389	0.330	0.302
Minimum....	0.268	0.300*	0.274	0.262	0.069	0.038†	0.054
Mean.........	0.717	0.809	0.857	0.529	0.203	0.187	0.160

* Regulation due to filling of reservoir affected low flow of 1925. Minimum value given based on estimate referred to upper Tuckasegee and Oconalufty records.

† This value possibly low due to regulation on water shed. Discharge for the four lowest consecutive weeks was 0.056 second-feet.

The record for the Cape Fear at Fayetteville starts in 1889. No other records are available until 1896 when observations were started on the French Broad at Asheville and the Yadkin River at Salisbury. Three years later, records were started on the Hiwassee River at Murphy and the Tuckasegee River at Bryson. These constitute the available long records of North Carolina stream flow.

It is a natural occurrence for stream flow to fall to a relatively low level towards the latter part of every summer and to remain relatively low well into the fall. Where records of stream flow are available, it is possible to ascertain the value of the lowest weekly flow occurring in each and every year covered by the records. By setting these values down in a column and computing their average, we determine in terms of weekly stream flow the value to which the stream falls on the average. Where this is done for a given stream, we will have determined a value which we might term average low flow. This is exactly what we have done in the case of table 2. On the basis just outlined, the figure at the bottom of each column reported as the

TABLE 3

Minimum weekly discharge of larger North Carolina Streams

YEAR	HIWASSEE AT MURPHY	TUCKASEGEE AT BRYSON	FRENCH BROAD AT ASHEVILLE	YADKIN AT SALISBURY	ROANOKE AT OLD GASTON	CAPE FEAR AT FAYETTEVILLE	FISHING CREEK NEAR ENFIELD	STATE AVERAGE OF LOW WEEKLY FLOW OF EACH YEAR AS PERCENT OF MEAN ANNUAL	STATE INDEX—PERCENT OF AVERAGE LOW FLOW	YEAR
	Drainage area, square miles									
	410	673	949	3,400	8,350	4,290	462			
	Mean annual, second-feet per square mile									
	2.41	2.46	2.38	1.47	0.981	1.15	1.21			
	Discharge as percent of mean annual									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	
1889						24		24	85	1889
1890						18		18	64	1890
1891						28		28	91	1891
1892						10		10	35	1892
1893						12		12	42	1893
1894						14		14	49	1894
1895						10		10*	35*	1895
1896			29	24		17		23	81	1896
1897			26	24		7		19	67	1897
1898	34	33	32	31		14		29	102	1898
1899	29	18	33	32		14		25	88	1899
1900	28	33	32	32		9		33	116	1900
1901	44	39	(78)	54		26		48	170	1901
1902	21	26		36		9		31	110	1902
1903	21	24		37		11		31	110	1903
1904	16	21	13	24		20		31	110	1904
1905	26	29	35	35		16		28	99	1905
1906	(57)	(62)	71	52		21		(53)	(187)	1906
1907	46	38	21	38		12		31	110	1907
1908	33	31	50	50		(29)		39	138	1908
1909	38	39	52	48		16		39	138	1909
1910	30	32	45	37		19		33	106	1910
1911	27	33	28	24		15		25	88	1911
1912	35	38	46	36	18	13		31	109	1912
1913	24	33	41	40	25	20		31	109	1913
1914	20	24	30	28	11	13		21	74	1914
1915	25	46	54	41	30	17		36	127	1915

* Only one record, Cape Fear at Fayetteville, available for the period 1889–1895, and the values given are to be considered as only generally indicative of state-wide conditions. Stream flow of these early years is not thought to have been less than in 1925 or 1930.

TABLE 3—*Concluded*

YEAR	HIWASSEE AT MURPHY	TUCKASEGEE AT BRYSON	FRENCH BROAD AT ASHVILLE	YADKIN AT SALISBURY	ROANOKE AT OLD GASTON	CAPE FEAR AT FAYETTEVILLE	FISHING CREEK NEAR ENFIELD	STATE AVERAGE OF LOW WEEKLY FLOW OF EACH YEAR AS PERCENT OF MEAN ANNUAL	STATE INDEX—PERCENT OF AVERAGE LOW FLOW	YEAR
	Drainage area, square miles									
	410	673	949	3,400	8,350	4,290	462			
	Mean annual, second-feet per square mile									
	2.41	2.46	2.38	1.47	0.981	1.15	1.21			
	Discharge as percent of mean annual									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	
1916	40	39	44	(56)	22	15		36	127	1916
1917	40	40	36	36	13			33	106	1917
1918	31	35	31	30	11			28	99	1918
1919	24	45	34	42	18		23	31	110	1919
1920	29	41	45	41	17		10	30	106	1920
1921	25	37	33	30	11		4	23	81	1921
1922	27	27	29	37	13		8	23	81	1922
1923	26	28	33	31	31		8	26	92	1923
1924	16	26	32	37	27		(25)	27	95	1924
1925	11	12	11	18	18		15	14	50	1925
1926	13	27	18	19	14		8	17	60	1926
1927	25	30	25	22	24		9	22	78	1927
1928	46	50	54		27		17	39	138	1928
1929	41	43	38		(40)	27	24	35	123	1929
1930	18	23	20		7	3	7	13	46	1930
Maximum...	57	62	78	56	40	29	25	53	187	
Minimum...	11	12	11	18	7	3	4	13	46	
Mean.......	30	33	36	36	20	16	15	28.3	100	

"mean" may be considered to represent the average low flow (in terms of weekly discharge per square mile). Table 3 being analogous to table 2, except that it reports stream flow in percent of mean, can be interpreted on a similar basis with respect to the value of "mean" reported at the foot of each column. For instance in column (1) relating to the Hiwassee River, we find that the mean is 30 percent. This is interpreted to state that average low flow for the Hiwassee is 30 percent of the mean discharge of that stream. Correspondingly, the average low flow of the Roanoke River at Old Gaston is 20 percent of the mean.

In the preparation of table 3, some statistical liberties have been taken necessarily on account of inadequacy of data for doing otherwise. It was desired in the case of table 3 to determine *for each year* the average of the percentages to which the streamflow fell during the low week, and to have this average or composite percentage cover the longest possible period. This was done and the resulting figures appearing in Column (8), table 3, in an approximate way can be considered applicable to the State as a whole.[6]

Accepting Column (8) as being approximately correct only, we can proceed to determine the relative dryness of years during the period 1889–1930. The year 1906 shows up as having been the least dry during that period, the low week falling to only 53 percent of mean. Proceeding with our review, we find that the years 1892, 1893, 1894, and 1895 appear to have been exceptionally dry. The years 1894 and '95 witnessed a drought essentially Nation-wide in occurrence, and it can be accepted that streamflow in those years was low in this State. However, our figures for that period are supported only by the Cape Fear at Fayetteville record. This stream falls to exceptionally low values and for that reason, in terms of relative magnitude, as well as actual, we cannot safely say that the years referred to were dryer than 1925 and 1930, which experienced "lows" of 14 and 13 percent of mean annual, respectively. Accordingly, we are inclined to say that 1906 during this period has been the least dry year of record with 1930 the driest, 1925 being essentially its equal, with a full report for 1931 not yet available.

AVERAGE LOW FLOW

We have accepted the term, *average low flow* as defining a significant value. Approximately it defines the value of minimum (weekly) flow which a stream will experience in the year that may be described generally as normal. By reference to Column (8) we find that for the State as a whole *average low flow* is 28 percent of mean discharge. For the Hiwassee we find this value to be 30 percent; for the Tuckasegee, 33; for the French Broad, 36; for the Yadkin, 36; for the Roanoke, 20; for the Cape Fear, 16; and for the Fishing Creek, 15. It is apparent, therefore, that while 28 percent is a figure of State-wide

[6] Their applicability is weakened (1) by only one record being available for the period 1889–96; (2) by gaps; and (3) by the small number of records (7 only available of length) and their lack of representativeness to some extent.

significance for comparative purposes, the similar value for individual streams will depart widely.

As stream flow normally falls each year to approximately 28 percent of mean discharge, it is proper to say that we are not experiencing drought stream flow until this figure is lowered. We can say roughly that we are experiencing drought stream flow when the flow falls markedly below 28 percent of normal (the mean discharge) for any appreciable period due to lack of precipitation.

Considering *average low flow* as being defined by 28 percent of mean annual discharge for the State, we have developed Column (9) from Column (8) by computing the low value of stream flow as reported for each year in Column (8) as percent of average low flow. By reference to Column (9), we are able to identify those years during which we have experienced *higher low flow* and those in which we have had *lower low flow*. Moreover, their relative magnitude is made quickly apparent in this column, and in figure 1 to which attention is directed. On this scale, it is apparent again that the year 1906 was the least dry since 1889 and that the low weekly flow only fell to 187 percent of average low flow. On the same basis, we find that the years 1925 and 1930 experienced the low flows of record. In terms of *average low flow*, it appears that the low of 1925 was 50 percent and that of 1930, 46 percent, which would place 1930 as the low year of record considering the State as a whole. In order that the writer might be fully assured as to the correctness of this indication, the full body of streamflow data was reviewed. Findings are stated briefly. The Western part of the State was drier during 1925–26 than during 1930 to which likely may be added 1931. The Eastern part was less dry in the first drought than in the latter. Considering the majority of streams, lower low flows were experienced during 1925 or 1926 than have been observed during 1930–31. The 1930 drought was of severe proportions over a greater period of time, however, and in the East has been accompanied by extremely low flows, particularly in the case of the larger streams. It has extended over into 1931. While 1925 flows were particularly severe in the case of small streams, it seems proper to conclude that for the State as a whole, and in consideration of the period of duration, the 1930 drought was more severe from the standpoint of water shortage. The two year period 1930–31 will stand out as considerably drier than 1925–26.

In submitting the above, it is pointed out that a stream-flow

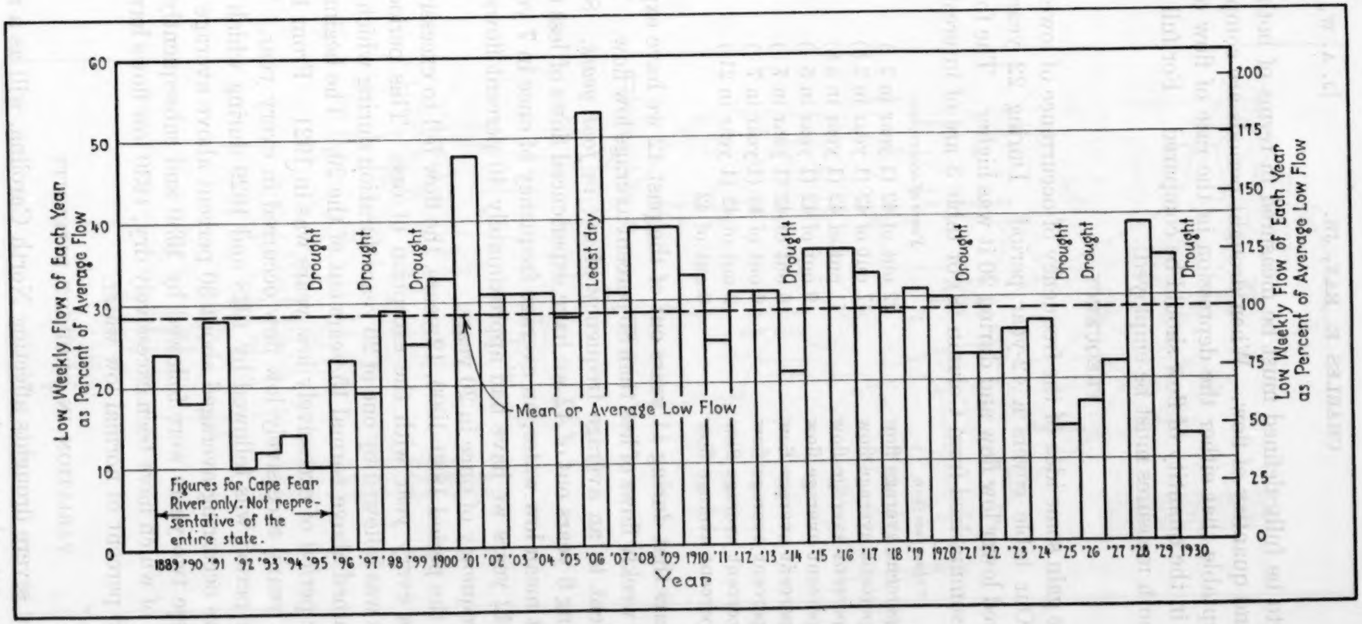

FIG. 1. LOW WATER OCCURRENCES IN NORTH CAROLINA, 1889–1930

drought to be fully defined must be measured in terms of both rate of flow and quantity of flow. When drought periods are compared, it is acceptable that either the depression in the rate of flow or the shortage in the quantity of flow should be compared. For full comparison both measures must be employed.

FREQUENCY

Can we gain some idea of the frequency of occurrence of lower low water? Our table covers a 42-year period. During 22 years we experienced lower low flow and during 20 it was higher The following data summarized from Column (8) of table 3 are of interest:

Values less than	*Years of occurrence*
100 percent average flow	22 out of 42 (1 year in 2)
90 percent average flow	17 out of 42 (1 year in 2.5)
80 percent average flow	11 out of 42 (1 year in 3.8)
70 percent average flow	9 out of 42 (1 year in 5)
60 percent average flow	6 out of 42 (1 year in 7)
50 percent average flow	6 out of 42 (1 year in 7)
40 percent average flow	2 out of 42 (1 year in 21)
30 percent average flow	0 out of 42

It appears that during 11 years out of the past 42 we have experienced low weekly flows of less than 80 percent average low flow. This is equivalent to an average frequency of *one in four years*. Similarly, during 6 years out of 42 we have experienced flows of less than 50 percent mean low water, an average frequency of once in 7 years. Twice in 42 years we have had approximately 40 percent flows, an average frequency of once in 20 years.

During the period 1889–1900, 12 years, the flow fell to excessively low values every year with the exception of one. This period of low values was followed by one of 20 years duration during which low flows remained above normal 15 years out of the 20. The beginning of another period of excessively low years was in 1921. From 1921 to 1927, 7 years, excessively low flow occurred in every year. The seven year period was followed by 1928 and 1929 during which the lowest flows occurring averaged about 30 percent above average low flow. These two years were followed by 1930 and subsequently by 1931, both of which have been excessively dry, 1930 low flows having fallen to 46 percent of normal low water.

VARIATION IN DROUGHT INTENSITY

The more severe droughts affecting North Carolina, will as a rule be found to extend over a large part of the country. Considering

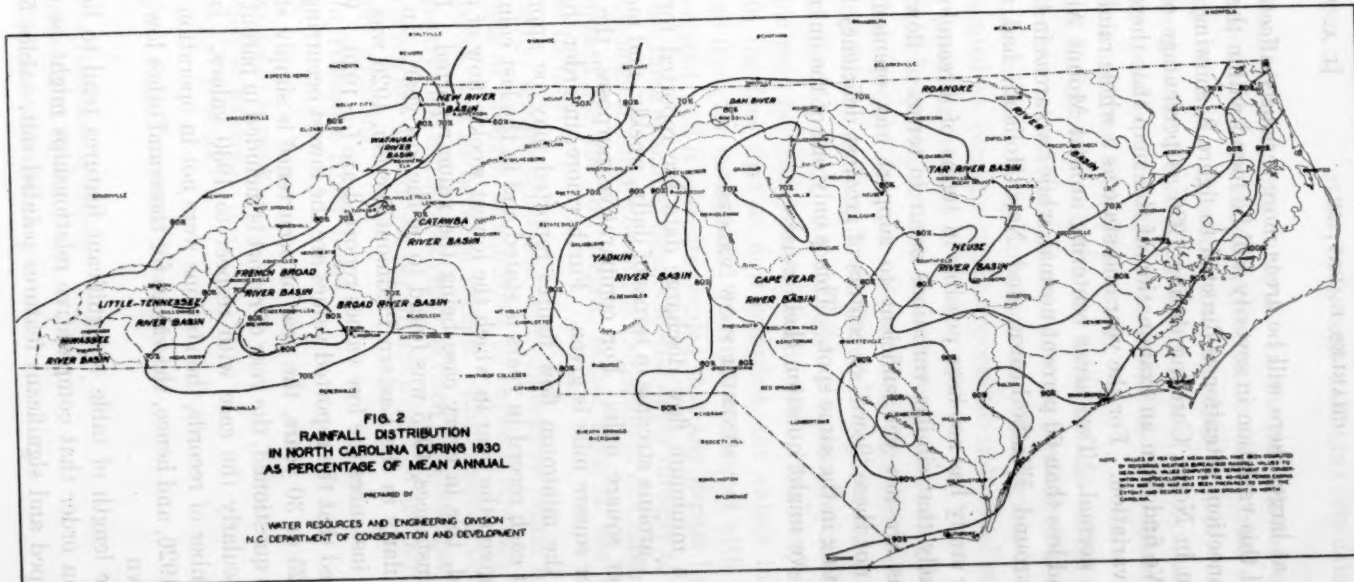

FIG. 2. MAP OF NORTH CAROLINA SHOWING RAINFALL DISTRIBUTION DURING 1930 AS PERCENTAGE OF MEAN ANNUAL

the nation at large, there will be areas more seriously affected than others, and this variation in severity will be found within the State. In this connection, attention is directed to figure 2, showing rainfall distribution in North Carolina during 1930 as percentage of mean annual. We find from an examination of this map that there was a very large variation. For the year and state as a whole rainfall was 75 percent normal. Two areas centering around Mount Airy and Brevard had less than 60 percent normal, while two areas in the east centering around Elizabethtown, and New Holland, had normal rainfall.

A similar study has not been possible in terms of streamflow, but it seems likely that similar variations occur in terms of flow. Our observations are not yet sufficient to support any opinion as to whether or not these "lows" or centers of greatest deficiency have a habit of hitting in the same spot. This is only one of the unknowns. As another we might question their cause.

MINIMUM FLOW VALUES

As table 4 minimum flow discharge data are reported for some sixty North Carolina streams in terms of daily, weekly, and monthly discharge per square mile. For comparative purposes, the mean discharge per square mile is given. Furthermore, in order that the stability of the minimum flow figures reported may be appraised, the length of each record in years is stated and in the last column of the table is given the year in which the lowest weekly flow of record was observed, this in every case being the value reported. In the majority of instances, 1925 was found to be the low year. In some cases, particularly in the Eastern Piedmont section, 1926 was lower and in a few instances the low values reported are for 1930. Where it is considered that the reported values are the lowest occurring during the last 25 or 30 years, the year of occurrence is simply stated. Where this is questioned, the year of report is included in parenthesis. This is particularly the case with respect to 1930 values. In the case of a number of records, the stations were not in operation prior to 1925 and 1926, and hence, the values for those and other low years are not known

Due to the length of table 4, significant features tend to be obscured, and in order that comparative relationships might be more easily developed and significant features pointed out, tables 5 and

6 have been derived from table 4. In the compilation of table 5, what seemed to be the most representative record from each River Basin was selected. This was the procedure in every case except with respect to the Neuse River where none of the available records seemingly could be considered representative. The figures reported in this case are from table 6 following.

Table 6 is distinctly a river basin table and the values therein reported are not taken from and are not to be considered as relating to or as representative of any actual stream. The figures in every case are computed as averages of the reports for individual stream flow records appearing in table 4.

The values reported in table 4 are in every case taken from official streamflow records secured coöperatively by the United States Geological Survey and the North Carolina Department of Conservation and Development. Accordingly, the data reported herein in this table may be considered authoritative. However, attention is called to the fact that as now compiled, the values included are separated from the records and descriptions thereof with which they are associated, and it is recommended that any person having occasion to use these or similar figures should apply directly to the United States Geological Survey or to the Department of Conservation and Development for the full record, rather than to use any values included in table 4.

Primarily, we are concerned with differences found to obtain in magnitude of drought streamflows as between streams, as between river basins, and as between regions. Emphasizing this the minimum weekly yield during 1925 may be cited for a few specific streams. Values given are second-feet per square mile, and are in round figures relatively speaking.

In the Hiwassee River Basin:

	second-feet
Hiwassee at Murphy	0.27
Nottely at Ranger	0.17
Valley at Tomotla	0.15

In the Little Tennessee River Basin:

	second-feet
Little Tennessee at Judson	0.35
Tuckasegee at Bryson	0.30
Nantahala at Almond	0.47

TABLE 4

Minimum flow discharge data for North Carolina streams

Compiled from coöperative records of U. S. Geological Survey and N. C. Department of Conservation and Development

STREAM	DRAINAGE AREA, SQUARE MILES YEARS	LENGTH OF RECORD	MEAN DISCHARGE PER SQUARE MILE		MINIMUM DISCHARGE PER SQUARE MILE				YEAR OF MINIMUM WEEKLY FLOW OF RECORD
					Day	Week		Month	
		Years	Sec.-ft.	M.g.d.	Sec.-ft.	Sec.-ft.	M.g.d.	Sec.-ft.	
Hiwassee River Basin									
Hiwassee at Murphy	410	33	2.41	1.56	0.119	0.268	0.174	0.334	1925
Nottely at Ranger	272	18	1.99	1.29	0.151	0.165	0.107	0.272	1925
Valley at Tomotla	106	20	2.60	1.68	0.113	0.151	0.098	0.202	1925
Little Tennessee River Basin									
Little Tennessee at Judson	668	34	2.80	1.810	0.285	0.348	0.225	0.416	1925
Tuckasegee at Bryson	673	33	2.46	1.591	0.149	0.300	0.198	0.462	1925
Tuckasegee at East Laporte	200	7	2.82	1.822	0.180	0.195	0.126	0.425	1925
Cullasaja Creek at Cullasaja	87	10	2.78	1.797	0.218	0.241	0.156	0.293	1925
Nantahala at Almond	177	18	3.20	2.068	0.447	0.474	0.306	0.530	1925
Cheoah at Johnson	175	11	2.91	1.881	0.217	0.268	0.173	0.310	1925
Oconalufty at Cherokee	133	8	2.94	1.900	0.421	0.451	0.291	0.519	1925
Cheoah at Tapoca	213	2			0.169	0.216	0.140	0.272	1925
Scotts Creek at Sylva	56	2			0.428	0.518	0.335	0.632	1930

French Broad River Basin									
French Broad at Asheville	948	32	2.38	1.538	0.292	0.274	0.177	0.346	1925
Swannanoa at Swannanoa	60	5	1.82	1.176	0.127	0.137	0.088	0.285	1926
North Toe at Spruce Pine	130	2			0.146	0.262	0.169	0.311	1925
Swannanoa at Biltmore	128	5	1.26	0.814	0.060	0.101	0.065	0.123	1925
Davidson near Brevard	41	9	3.05	1.971	0.366	0.440	0.284	0.586	1925
French Broad at Blantyre	296	10	3.05	1.971	0.487	0.530	0.342	0.632	1925
Pigeon near Crabtree	244	9	1.95	1.260	0.192	0.234	0.151	0.317	1925
Pigeon near Mt. Sterling	453	5	1.89	1.221	0.114	0.194	0.125	0.291	1925
French Broad at Calvert	104	6	3.03	1.958	0.558	0.558	0.361	0.658	1925
Nolichucky at Poplar	609	5	1.86	1.202	0.263	0.302	0.195	0.520	(1926)
N. Fork Swannanoa at Black Mountain	23	5	2.52	1.629	0.031	0.034	0.022	0.182	(1926)
Bee Tree Creek near Swannanoa	5.7	4	2.11	1.364	0.123	0.145	0.094	0.235	(1930)
S. Fork Mills near Pinkbeds	9.87	5	2.91	1.881	0.192	0.223	0.144	0.294	(1930)
Pigeon at Hepco	342	3			0.319	0.366	0.236	0.503	(1930)
Pigeon at Canton	134	2			0.328	0.373	0.241	0.456	(1930)
New River Basin									
South Fork New near Jefferson	207	2	1.28	0.828	0.314	0.358	0.233	0.453	1925
Broad River Basin									
Sandy Run near Boiling Springs	67	3	1.18	0.764	0.209	0.223	0.144	0.373	(1926)
Second Broad at Cliffside	230	5	1.24	0.802	0.078	0.178	0.115	0.290	(1926)
Main Broad near Boiling Springs	815	5	1.81	1.17	0.285	0.345	0.223	0.438	1925
Catawba River Basin									
Linville at Branch	65	8	2.09	1.35	0.123	0.185	0.120	0.212	1925
Little Sugar Creek near Charlotte	41.4	6	1.05	0.679	0.039	0.053	0.034	0.075	1925
Henry Fork at Henry River	80	5	1.42	0.918	0.051	0.238	0.154	0.341	(1926)

TABLE 4—*Concluded*

STREAM	DRAINAGE AREA, SQUARE MILES	LENGTH OF RECORD	MEAN DISCHARGE PER SQUARE MILE		MINIMUM DISCHARGE PER SQUARE MILE				YEAR OF MINIMUM WEEKLY FLOW OF RECORD
					Day	Week		Month	
		Years	Sec.-ft.	M.g.d.	Sec.-ft.	Sec.-ft.	M.g.d.	Sec.-ft.	
Yadkin River Basin									
Yadkin at Salisbury	3,400	31	1.47	0.950	0.206	0.262	0.169	0.353	1925
Yadkin near North Wilkesboro	300	4	1.19	0.770	0.304	0.340	0.220	0.494	1926
Fisher near Dobson	109	10	1.54	0.996	0.156	0.193	0.125	0.299	1925
Yadkin near Yadkin College	2,250	2			0.283	0.336	0.217	0.385	(1930)
South Yadkin at Cooleemee	560	1			0.098	0.257	0.166	0.311	(1930)
Cape Fear River Basin									
Cape Fear at Fayetteville	4,290	30	1.15	0.743		0.038†	0.025	0.064	1930
Deep at Ramseur	343	8	1.09	0.705	0.023	0.026	0.017	0.039	1930
Morgan Creek near Chapel Hill	27	8	1.20	0.776	0.016	0.027	0.017	0.035	1925
West Fork Deep near High Point	33	4			0.060	0.082	0.053	0.167	1930
Cape Fear at Lillington	3,530	7	0.962	0.622	0.018*	0.020*	0.013	0.023	
Reedy Fork Creek near Summerfield	34.1					0.194	0.125	0.245	(1926)
Horsepen Creek near Battle Ground	15.9					0.132	0.085		(1926)
East Fork Deep near High Point	13.9					0.173	0.112	0.187	(1930)
Haw at Haw River	592	2			0.008	0.036	0.023	0.100	(1930)
Haw at High Rock Mills near Benaja	168	2			0.065	0.083	0.054	0.150	(1930)
Haw River near Pittsboro	1,340	2			0.016	0.037	0.024	0.044	(1930)

Neuse River Basin									
Flat near Bahama	150		0.855	0.552	0.004	0.005	0.003	0.018	1925
Dial Creek near Bahama	4.9	5	0.731	0.472	0.000	0.000	0.000	0.010	1926
Neuse near Clayton	1,230	3			0.071	0.107	0.069	0.150	(1930)
Contentnea Creek near Hookerton	696	2			0.096	0.096	0.062	0.104	(1930)
Roanoke River Basin									
Roanoke at Old Gaston	8,350	19	0.981	0.634	0.067	0.069	0.045	0.097	1930
Dan near Francisco	119	6			0.261	0.310	0.200	0.428	1930
Tar River Basin									
Fishing Creek near Enfield	462	12	1.208	0.781	0.048	0.054	0.035	0.061	1921
Tar near Nashville	593	2			0.064	0.087	0.056	0.139	(1930)

* Estimated values made necessary by regulation.

† Possibly low due to regulation.

Note: (1) This table is submitted not for the specific information contained but to illustrate the great differences in minimum flow found to obtain as between different streams, different river basins, and different regions. Where it is desired to make use of these or other records, it is suggested that the full record be obtained together with station descriptions.

(2) Where the year of minimum weekly flow has been placed in parenthesis, it is to be considered that lower flows are likely to have occurred within recent years, for which records are not available.

TABLE 5

Representative records from major river basins summarizing minimum flow discharge

STREAM	DRAINAGE AREA, SQUARE MILES YEARS	LENGTH OF RECORD	MEAN DISCHARGE PER SQUARE MILE		MINIMUM DISCHARGE PER SQUARE MILE					
					Day		Week		Month	
		Years	Sec.-ft.	M.g.d.	Sec.-ft.	M.g.d.	Sec.-ft.	M.g.d.	Sec.-ft.	M.g.d.
Nottely at Ranger	272	18	1.99	1.29	0.151	0.097	0.165	0.106	0.272	0.176
Little Tennessee at Judson	668	34	2.80	1.81	0.285	0.184	0.348	0.225	0.416	0.268
French Broad at Asheville	948	32	2.38	1.54	0.292	0.188	0.274	0.177	0.346	0.213
New at Jefferson	207	2			0.314	0.203	0.358	0.231	0.453	0.292
Second Broad at Cliffside	230	5	1.25	0.81	0.078	0.052	0.178	0.115	0.290	0.187
Little Sugar Creek, Charlotte	41.4	6	1.05	0.68	0.039	0.025	0.053	0.342	0.075	0.048
Yadkin at Salisbury	3,400	31	1.47	0.95	0.206	0.133	0.262	0.168	0.353	0.229
Morgan Creek near Ch. Hill	27	8	1.21	0.78	0.016	0.010	0.027	0.017	0.035	0.022
Neuse River*			0.793	0.51	0.043	0.028	0.052	0.033	0.070	0.045
Dan at Francisco	119	6			0.261	0.169	0.310	0.200	0.428	0.275
Fishing Creek near Enfield	462	12	1.208	0.78	0.048	0.031	0.054	0.035	0.061	0.039
Average			1.57	1.01	0.158	0.102	0.189	0.122	0.254	0.164
Average of two lowest records			0.995	0.64	0.030	0.019	0.039	0.025	0.052	0.034

* No record for the Neuse River Basin seems to qualify as representative, and the data given is taken from table 6.

In the Cape Fear River Basin, but in 1930 instead of in 1925, as above:

	second-feet
Cape Fear at Fayetteville	0.04
Deep at Ramseur	0.03*
Morgan Creek at Chapel Hill	0.06
Horsepen Creek at Battle Ground	0.15
East Fork Deep River	0.27

* Affected by regulation and possibly a little low.

TABLE 6

Average minimum flow by River Basins computed from data of table 4

BASIN	MEAN DISCHARGE PER SQUARE MILE		MINIMUM DISCHARGE PER SQUARE MILE					
			Day		Week		Month	
	Sec.-ft.	M.g.d.	Sec.-ft.	M.g.d.	Sec.-ft.	M.g.d.	Sec.-ft.	M.g.d.
Hiwassee	2.33	1.51	0.128	0.083	0.194	0.125	0.27	0.17
Little Tennessee	2.84	1.84	0.279	0.180	0.322	0.208	0.40	0.26
French Broad	2.32	1.50	0.239	0.154	0.278	0.178	0.38	0.25
New	1.90*	1.23*	0.314	0.203†	0.358†	0.231†	0.45†	0.29†
Broad	1.24†	0.80	0.191	0.123	0.248	0.160	0.37	0.24
Catawba	1.52	0.98	0.071	0.046	0.158	0.102	0.21	0.14
Yadkin	1.40	0.90	0.209	0.135	0.277	0.179	0.37	0.24
Cape Fear	1.10	0.71	0.050	0.032	0.074	0.048	0.11	0.07
Neuse	0.79	0.51	0.043	0.028	0.052	0.034	0.07	0.04
Roanoke	0.98†	0.63	0.164	0.106	0.189	0.122	0.26	0.17
Tar	1.21†	0.78	0.056	0.036	0.075	0.048	0.10	0.07
Average	1.60	1.03	0.158	0.102	0.202	0.130	0.27	0.17
Average of 2 low Basins	0.94	0.61	0.046	0.030	0.063	0.041	0.09	0.06

* Estimated.

† These values not well supported.

Note: This table is submitted not as specific information but to emphasize the great differences in minimum flow found to obtain as between river basins. Differences in flow as between streams both in the same basin or region, and in different basins and regions is emphasized by tables 4 and 5.

In the Neuse River Basin near Durham:

Flat River (150 square miles) experienced in 1926 a low flow of only 0.7 second-feet (0.5 m.g.d.) which corresponds to a yield per square mile of only 0.005 second-foot. Dial Creek (5 square miles) was dry for several weeks during both 1925 and 1926.

During 1930 the unit discharge of the Roanoke River at Old Gaston fell to 0.069 second-feet.

Table 6 is in terms of average yield per square mile under conditions of minimum flow, each river basin being reported separately. It should be expected that mountain watersheds in areas of high precipitation would be most productive and the data emphasize this. In terms of weekly yield per square mile we find the Little Tennessee Basin most productive with 0.32[7] second-feet, with the Neuse least productive at 0.05 second-feet, or approximately one-sixth that of the western area. For the two basins of lowest flow, the similar figure is 0.063 and for the State as a whole approximates, 0.2 second-feet. The range in value of yield per square mile is amazingly large even between basins, and would be increased as between individual streams. Attention is directed to these values and to others in tables 5 and 6, not as to their actual magnitudes, but in emphasis of the differences in yield of the different watersheds and basins. They make evident the fact that while broad ranges in yield may be established for regions and river basins, the yield from different watersheds will vary tremendously in magnitude. We must conclude again that streams are strangely individual in their behavior and singly constitute individual problems.

An evaluation of the factors responsible for this great variation in magnitude would be extremely interesting and of value. Full consideration of this aspect is not possible, but the principal factors may be named as precipitation, topography, character of soil, and geologic formation. The precipitation is determined to a considerable extent by topography which in turn is determined by geologic formation.

RANGE OF MINIMUM IN MOUNTAINS

Records for mountain streams are sufficiently numerous to permit a more exact study of variation than is possible for other sections. As figure 3 we have made a plot of minimum weekly streamflow per square mile against size of drainage area. Streams are included for mountain streams westward of the Catawba and including Linville River from that basin. We are thus enabled to visualize more easily and exactly the wide differences in value of the minimum found to obtain for different streams. It is made evident that these differ-

[7] The value for the New River Basin, 0.358, actually is higher, but is the value from a single station only and is disregarded.

ences are to a small degree only accounted for by the size of the watershed. The scatter or dispersion of points is great but they fall so as to suggest the drawing of enveloping curves and this has been done on the basis of outer curves to define the maximum range of minimum flow values and with the inner curves defining the average range as indicated by the points plotted. Streams in areas of relatively high precipitation would plot toward the upper curve and those in low areas would plot toward the lower curve.

For streams of 50 square miles and less it appears that the watershed of extremely high yield might never fall below 0.70 second-feet per square mile in flow, whereas a less productive area of that size might conceivably experience zero flow.

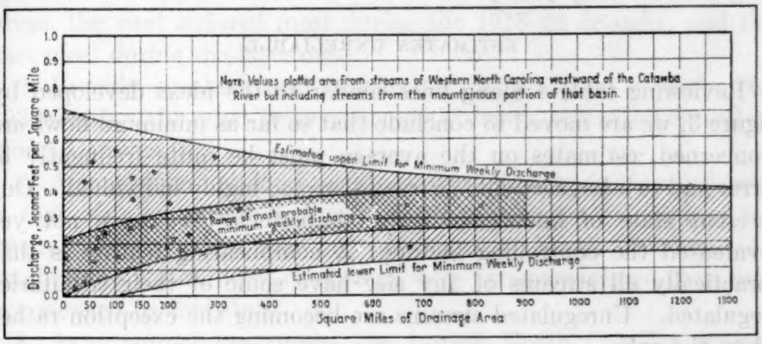

FIG. 3. INVESTIGATION OF RELATION BETWEEN MINIMUM WEEKLY STREAM FLOW AND SIZE OF DRAINAGE AREA FOR WESTERN N. C. STREAMS

For streams of 150 square miles and less it would not be surprising to find minimum flow ranging between 0.62 and 0.02 second-feet per square mile. For streams of 300 square miles, the range narrows to 0.57 down to 0.06 second-feet. The 600 mile stream would be expected to have its minimum flow confined to the range 0.48 to 0.13 second-feet. In the 1200 square mile class, the range in all probability might be confined between .040 and 0.17. For the sizes of watershed cited, the range for the larger stream is the least. Even so, the spread for the 1200 square mile stream is from 0.40 to 0.17, a range of 0.23 second-feet which is almost 150 per cent of the lower possible value.

Figure 3 is considered significant to the extent that it emphasizes that streams draining areas adjacent and apparently similar in

physical aspects may be highly dissimilar with respect to drought stream flow. In further emphasis of this fact, an experience of 1930 is cited. A record had been maintained on a stream of 27 square miles drainage area since 1923. Confluent to this stream and a part of the larger area was a smaller stream of 5 square miles. The flow of this smaller stream was measured during September and October for purposes of comparison with the larger stream. It was found that during this low flow period the contribution from each square mile of the smaller stream was approximately 5 times that from the remainder of the watershed. While not particularly apparent from a casual examination, it has since been established that the soil of the smaller area consists largely of sand and gravel, while that of the larger area is largely clay.

ESTIMATES UNRELIABLE

Reviewing table 4 along lines similar to the ideas developed by figure 3, we are moved to conclude that so far as minimum flows are concerned, estimates on the average must be quite frequently in error and to a large extent. Streams are too highly individual. Our present state of knowledge is too imperfect. We have not yet evaluated the controlling factors. A complicating feature is that practically all streams of any size have some of their tributaries regulated. Unregulated streams are becoming the exception rather than the rule.

SUMMARY

Essentially this study has presented an opportunity only to assemble the available body of drought stream flow data for the State, to review the information collected, and to draw general conclusions. It has not been possible to search out the factors controlling stream flow and to evaluate them in relation to minimum stream flow. Such studies must await later attention on the part of other students. The general conclusions which have developed out of this study are enumerated as follows:

1. In the 42-year period beginning with our first stream flow record, we have experienced extremely low drought flows on a State-wide basis three times. These occurrences were in 1894–95, 1925–26 and in 1930–31. Each time the depression in flow covered two-year periods.

2. Less severe but of drought proportions were the flows of the

years 1897, 1911, 1914, 1918, and 1921. As a rule portions of the State were more seriously affected than others.

3. During 6 years out of 42 we have had low flows less than 60 percent of what we have termed average low flow and which may be referred to here as normal low water. Six occurrences in 42 is equivalent to 1 in 7.

4. In terms of depressed rate of flow, the drought of 1925–26 was more severe than that of 1930–31 for the Piedmont and Western part of the State, while in the eastern Piedmont and eastward 1930–31 has been the more severe.

5. In terms of shortage in quantity of water due to long duration of drought accompanied by marked depression in rate of flow 1930–31 must be rated as markedly drier than 1925–26. As between areas, the west suffered most during the 1925–26 drought, and the east most during the later one.

6. Broadly speaking and relating to the State as a whole, the 1930–31 drought must be considered the most severe on record in North Carolina.

7. A conclusion not developed in the text, but made of record here is that we may expect in the future to experience droughts of far greater severity than any yet of record in North Carolina. In neighboring states, 1930 conditions were far more severe than any experienced in this state.

8. As a normal occurrence, the typical North Carolina stream may be expected annually in the low week to approximate 28 percent of its mean annual value.

9. During 1925, the minimum weekly stream flow for some of the larger streams was as follows:

STREAM	PERCENT MEAN ANNUAL	PERCENT AVERAGE LOW FLOW
Hiwassee	11	37
Tuckasegee	12	24
French Broad	11	30
Yadkin	18	90
Roanoke	18	90
Fishing Creek	15	100

10. The data bear out the generally known fact that for both normal and drought conditions, the per square mile yield of mountain streams is usually greatly in excess of that found in the Piedmont and more eastern areas.

11. Streams having adjacent watersheds, being approximately of the same size, and apparently of approximately the same general physical characteristics are found to vary tremendously in per square mile yield.

12. Streams of five and ten square miles have been observed to dry up.

13. Streams of larger area have been observed to dwindle in flow until only a trickle remained. For more than a week, in 1926, the Flat River near Durham having 150 square miles of watershed registered less than 0.7 second-feet which is less than 0.5 millions gallons daily.

14. Due to the vegetation draft on ground water, the drought flow of small streams may vary during each day by as much as 30 percent or more.

15. An estimate of minimum flow for a stream where records are lacking cannot be considered reliable unless it is based on an exhaustive field investigation likely to be more costly than gaging the stream. Errors in such estimates may easily differ from the true value by more than 100 percent.

16. Minimum flow yields as between watersheds will be found to differ more in magnitude in the case of small areas than in larger ones. Figure 3 is illustrative of this.

17. It is evident that streams are highly individual, that generalizations are questionable, and as pointed out that estimates are likely to err greatly.

RECOMMENDATION

Perhaps the most outstanding conclusion to be drawn from this paper is that stream flow is a highly complicated phenomenon and that our present understanding is an imperfect one. It is evident also that the body of data now available is too inadequate to permit comprehensive investigation of its various phases. Two recommendations are made in this connection.

1. Governmental agencies including those of the Federal, State, and Municipal Governments should function through a coördinated program to expand observational studies relating to stream flow, rainfall, evaporation, transpiration, ground water release and related fields.

2. In coördination with the above program and as the body of data becomes sufficient, research should be instituted in order that the

several factors controlling minimum stream flow may be made apparent, their effects evaluated, and the way pointed to more efficient, economic utilization of our water resources, and the capital investment in our water supplies and waste treatment plants, properly proportioned to our stream capacities.

DISCUSSION

THORNDIKE SAVILLE:[8] The writer believes that Mr. Ray has presented in this paper not only a valuable statistical analysis of minimum stream flow in North Carolina, but in his opening and concluding paragraphs has evidenced an understanding of what may be called the philosophy of stream flow upon which all of us would do well to ponder. Too often governmental agencies, both federal and state, are content to collect and publish statistical data without an attempt at analysis. The very agencies that may be supposed to be in the best situation to study, analyze, criticize and explain the utility of the data they collect, are wont to shirk the responsibility and leave it to the practicing engineer to develop as best he can conclusions from an array of figures which often appear to be confusing and conflicting. This paper is a valuable contribution on the part of one who has had an important part in the stream gaging program in North Carolina and presents a phase of the subject in a manner which will assist those concerned with the utilization of water resources in the State to better interpret the significance of stream gaging statistics relating to minimum stream flow.

It may be pertinent to comment briefly on a few of the points featured in Mr. Ray's paper. Attention is called to the common use in many governmental hydrological studies of the term "normal." The writer believes this should never be used in connection with natural phenomena. Certainly no value of rainfall or stream flow is "normal" in the generally accepted meaning of the term. It is an exceedingly rare event when the arithmetic average or mean value is found in arrays of hydrological data. Thus (table 2) for the Yadkin River there were only 10 out of 32 years in which the minimum weekly stream flow was within even 10 percent of the mean (or so-called "normal") value. On the Tuckasegee River only 8 out of 33

[8] Professor of Hydraulic and Sanitary Engineering, University of North Carolina. Chief Engineer, Department of Conservation and Development, Chapel Hill, N. C.

years were within 10 per cent of the mean. In no year was the flow the same as the mean value. Therefore the use of the term "normal," instead of average or mean, is likely to convey an erroneous impression as being a value which usually occurs. Actually it almost never occurs. The mean is a value about which individual occurrences fluctuate to a greater or less degree depending upon a great variety of conditions.

Another statistical fact of interest is that in most arrays of hydrological data there are more occurrences below the mean than above. This is well illustrated by table 2 showing that for every stream but one there were a greater number of years when minimum stream flow was below the mean than above it.

Hydrologists and meteorologists have never agreed on any generally acceptable definition of the term "drought." Rainfall droughts and stream flow droughts do not always occur simultaneously or in equal severity. Mr. Ray has made an interesting and novel approach to defining a stream flow drought in terms of the "average low flow." The writer would prefer a somewhat less concise, but perhaps more statistically accurate definition of this term, and suggests the following:

> *Average low flow* is the arithmetic average[9] of the lowest weekly flow each year for the period of record, and is an arbitrary value, or index, which may be used to indicate the severity of a "stream flow" drought. When weekly stream flow falls below this value drought conditions are being approached, and the farther below this value such flows may be the more severe the drought.

From figure 1 it may be stated arbitrarily and provisionally that for North Carolina streams on the whole, there is a moderate drought when weekly stream flow falls below 75 per cent of the average low flow (approximately 22 per cent of the mean annual flow), and that a severe drought exists when weekly stream flow falls below 50 per cent of the average low flow (approximately 15 per cent of the mean annual flow).

The use of any index, such as average low flow or the so-called state index, as in column 10 of table 3, must be applied with caution. Thus the state index shows 1930 as the driest year from a stream flow standpoint. Yet on three western streams there were two or more years when the weekly stream flow was lower than in 1931. One or

[9] See preceding definitions of average or mean.

two very high or very low values will greatly affect the average in a small number of values, such as the seven used in computing the state average annual low values in table 3. Mr. Ray has warned against using the tables in the paper as presenting other than *comparative* values.

From figure 1 it will be seen that from 1900 to 1910 inclusive and from 1915 to 1930 inclusive the average minimum weekly flow in no year became as low as the "average low flow" for the period of record. This emphasizes the necessity of continuous long term records if the true picture of stream flow variation is to be attained. Incidentally there is every reason to suppose that minimum low flows heretofore recorded are greater than some to be experienced in the future. The value of "average low flow" will also change with increased length of record. In general the average determined from 40 to 50 years of record will be within 3 to 4 percent of the very long period average.

A word may be said with relation to the present drought. It was predicted early in July by the Department of Conservation and Development that notwithstanding possible high rainfall in July and August, the fall stream flow would be unusually low. This prediction has been fulfilled. It was based on extensive studies of stream flow, rainfall and ground water levels during the preceding year. It now appears that new minimum low flows are likely to occur on eastern streams in November, in spite of a good deal of relief due to cessation of water use by vegetation. On many streams total annual stream flow will be a minimum, reflected in reduced output from hydro-electric plants and greater total draft on municipal storage reservoirs than ever experienced previously. The present drought is really an extension of that of last year, and as soon as it appears definitely at an end the Department of Conservation and Development hopes to issue a detailed analysis of the conditions producing the drought and recovery from it.

CEDAR RAPIDS WATER SOFTENING AND FILTRATION PLANT[1]

By L. R. Howson[2]

The water works plant of Cedar Rapids was started in 1875 in its present location. The source of supply has been largely from the Cedar River, supplemented at times by drawing from shallow wells on an island in the river and from deep wells penetrating the underlying sandstones. The old location, due to the encroachment of industry, is not well adapted to water works use, being hemmed in on one side by the river, on another by the Northwestern Railroad and on the other two sides by the Quaker Oats Company's plant. All were agreed that no enlargement on the present site was practicable or desirable.

The officials of Cedar Rapids have long recognized the ultimate necessity of abandoning the old plant, and various plans for securing a new water supply have been presented and successively defeated.

WATER SUPPLY SOURCES

In the summer of 1928, engineers were employed to make a comprehensive investigation and report upon all the water supply resources available to the City of Cedar Rapids with instructions to place these supplies on comparable bases as to the character of the supply, cost of development and the annual cost, including operation and fixed charges. The investigation included a study of the following sources of supply:

(a) Cedar River
(b) Sandstone deep wells
(c) Prairie Creek sand wells
(d) McLeod and Marion Springs
(e) Limestone wells
(f) Cedar River gravel wells

All sources were compared as to adequacy for present needs and capability of future enlargement, the cost of development, annual

[1] Presented before the Missouri Valley Section meeting, November 6, 1930.

[2] Alvord, Burdick and Howson, Engineers, Chicago, Ill.

cost, including operation and fixed charges on required expenditures, hardness, temperature, freedom from taste and odors and sanitary quality.

In considering the question of adequacy, it was necessary to make a study of population growth, past, present and probable future. The present population of approximately 55,000 people was estimated to be 75,000 in 1940 and 170,000 by 1970. Data on this problem are shown in figure 1.

Based upon the forecast of population and a detailed study of the statistics for the past 25 years covering the population, services,

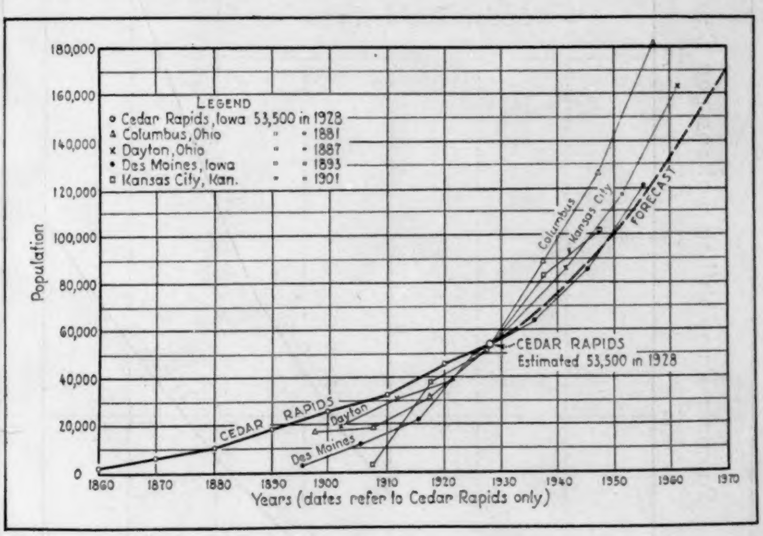

FIG. 1

people per service and gallons of water used per service and per capita, a forecast of water requirements was made, the results of which are shown graphically on figure 2. This figure indicates that the present average daily use of about 4½ million gallons is estimated to increase to approximately 6½ million gallons on an average day in 1940 with maximum day's use at that time reaching 11.2 m.g.d. 1940 conditions were used in all cases as the basis for present construction.

Of the available sources of supply, the Prairie Creek, McLeod Springs and Marion Springs were eliminated from the standpoint of inadequacy for either present or future needs. A development from

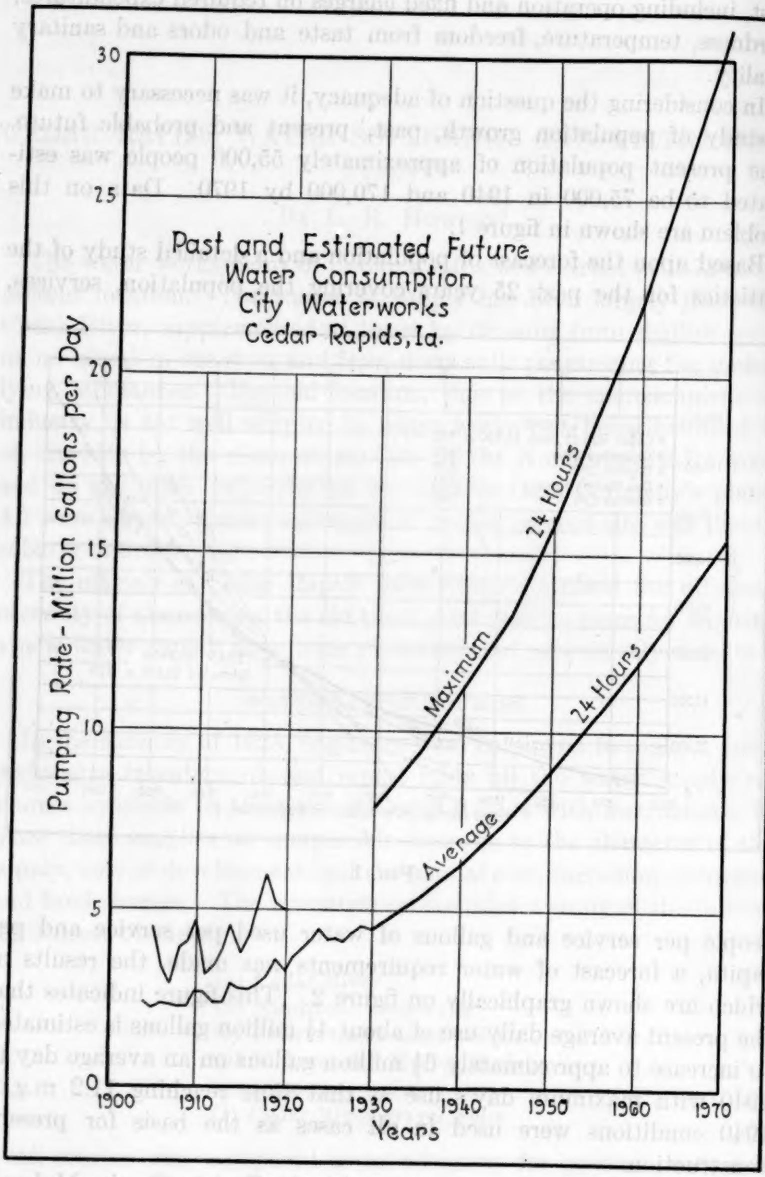
Past and Estimated Future
Water Consumption
City Waterworks
Cedar Rapids, Ia.
Pumping Rate - Million Gallons per Day
Years
0
5
10
15
20
25
30
1900
1910
1920
1930
1940
1950
1960
1970
Maximum 24 Hours
Average 24 Hours

FIG. 2

the limestone was also found to be impracticable for so extensive a requirement as the future for Cedar Rapids. The selection, therefore, narrowed to the Cedar River, sandstone deep Wells or the Cedar River gravel wells, all of which were believed to be adequate.

All of the available sources of supply yield relatively hard waters and softening would be advisable with any one. All estimates and comparisons were therefore based on softening to about 4 grains per gallon or somewhat less than one-half the average hardness of the old filtered river supply. Figure 3 shows graphically the facts relative to the hardness of the various available supplies.

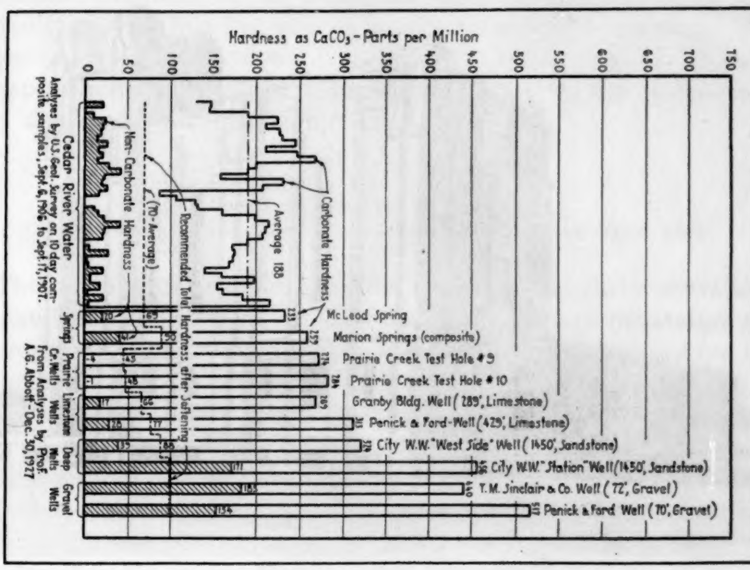

FIG. 3

FILTERED, SOFTENED CEDAR RIVER SUPPLY RECOMMENDED

As an outgrowth of this investigation, it was recommended that the City proceed to develop the Cedar River supply, filtered and softened, using electricity for pumping. The abandonment of the existing plant was recommended, together with the construction of a modern plant to be built on the east bank of the Cedar River well upstream from the City. A suitable location was indicated approximately opposite Ellis Park. It was estimated that the total expenditure, exclusive of land, would be $640,000.

The program recommended was submitted to the voters and carried by a large majority. The engineers were instructed to prepare plans and specifications and bids were taken in the early summer of 1929. Work proceeded at a good rate and the plant was completed and ready for operation in the late summer of 1930. What follows hereinafter will be a more detailed description of the new works.

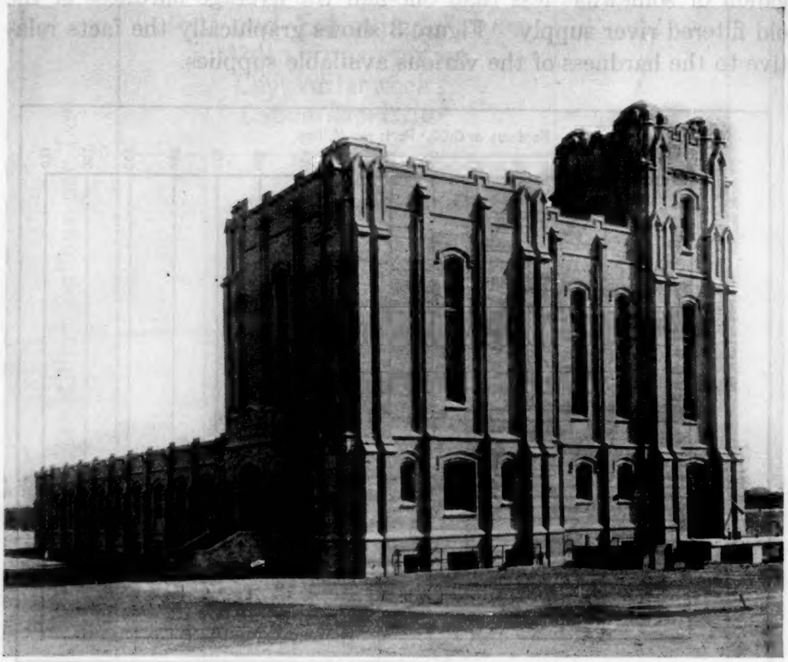

FIG. 4. NEW WATER PURIFICATION PLANT, CEDAR RAPIDS, IOWA

THE NEW WATER WORKS

The new construction embraces a low lift pumping station located on the east bank of Cedar River at a point some 2 miles upstream from the center of the City and 4500 feet upstream from the main purification plant and high lift pumping station.

The low lift pumps discharge into a 30-inch cast iron force main connecting the low lift with the high service plant. The high service plant includes mixing facilities, sedimentation and recarbonation basins, mechanical filters and an electric driven high service pumping

station whose pumps discharge into mains connecting with the present distribution system of the City and the 8 million gallon high service reservoir.

Low lift station

The low lift station is of the automatic remote control type. The water enters the station through two 36-inch cast iron intakes, extending out into the river and in approximately 6 feet of water. The pipes are anchored to piling and protected by rock embankment. The intakes terminate at the shore end in a screen and suction well equipped with iron bar screens having 1½-inch clear opening. The pump suctions turn down into this well, the bottom of which is approximately 11 feet below the ordinary water surface in the river.

The low lift pumping equipment consists of:

1–5 m.g.d. motor centrifugal
1–7.5 m.g.d. motor centrifugal
1–10.0 m.g.d. combined motor and gasoline engine driven unit

The pumping installation is so designed that the entire operations may be controlled from the station panel in the high lift station approximately 4500 feet distant. The sequence of operations for remote control is as follows:

Pressing the "start" button for the low lift unit will start the priming pump and open the solenoid valve in the priming line of the unit to be started. When the unit is primed and water has risen into the float chamber of the float switch above the pump casing, the low lift pump control is actuated by the float switch. The pressure developed in the pump discharge line after the unit is up to speed, stops the priming pump. Pressing of the "stop" button in the main station shuts down the low lift pump.

The control equipment provides protection for the low lift equipment in case of abnormal conditions such as failure of the low lift pump to prime, the loss of suction or discharge pressure in the low lift station, the overheating of the motor winding, the occurrence of under voltage conditions of less than 75 percent of normal for one minute or the flooding of the low lift pump pit.

The building is heated by a thermostatically controlled, oil burner fired, pipeless furnace.

Aeration

At rather infrequent times, the river water carries taste and odors. Aeration is provided. This will be supplemented at a later date if necessary by the adoption of one of the taste and odor removal or prevention processes which are now being developed and demonstrated.

The aeration is through nozzles of the "Sprayco" type, each having a discharge capacity of 115 gallons per minute at 15 feet head. These nozzles are attached to a header running entirely around the mixing chambers into which the water falls after aeration.

Chemical facilities

Chemicals are received at the plant in bulk in carload lots. They are unloaded from the cars by a vacuum unloading system having a capacity of 7½ tons per hour. The materials are discharged into a hood in which the air is separated from the chemicals, the latter discharging through a hopper on to a 9 inch spiral conveyor 32 feet in length which carries the chemical to any one of three steel storage bins. These bins are 12 feet in diameter with an average height of 24 feet and have a total storage capacity of approximately 180 tons. Two will ordinarily be used for lime and one for alum.

Four chemical feeders are provided, two for lime, each having a capacity of from 50 to 1000 pounds per hour. These feeders will handle either pulverized or lump materials. Two other feeders are provided to handle pulverized alum, lime or soda-ash, their capacities being adjustable from 10 to 500 pounds per hour.

The lime machines are equipped with slakers and the alum machines with dissolving boxes.

Mixing facilities

The design of the plant provided for a rapid agitation and mixing of the chemicals with the water in what are termed pre-mixing basins, having a storage period of approximately two minutes, the agitation being provided by change in direction of flow supplemented by air discharged through perforated pipes in the bottom of the basins. Air compressor capacity of 50 cubic feet per minute is provided.

From the pre-mixers, the water with the chemicals passes to two mechanically operated stirring basins, each with a capacity for 30 minutes detention.

The basins are 50 feet square by 22 feet deep. The stirring mechanism consists of vertical shaft with two extension arms to each of which are attached six steel plates which drag through and stir the water after the chemicals have been thoroughly mixed with it in the premixers. The plates swing loosely on the arms to prevent excessive starting load on the motor.

The water enters the mixing basins tangentially at the bottom and leaves at the top. The mechanism is operated by a 5 H. P. motor.

Clarifier and settling basin

The mixing or re-action basins are followed by two settling basins, each having a capacity of 2 hours at rated plant capacity. One of these basins is now equipped with Dorr Clarifier. Provision is made for installing similar mechanism in the second tank at a later date. The mechanism installed is of the Dorr traction type.

The plans contemplated a low brick superstructure with wood roof over the mixing and settling tanks. Funds were not available for their construction at this time. The anchor bolts, lighting conduits all were installed with the future superstructure in view.

Series vs. parallel operation

The plant is so arranged, on account of the variable character of the raw water, as to permit of either parallel or series mixing and settling. The plant will ordinarily be operated in series, but the sequence of chemical feeding will depend upon the character of the raw water.

Ordinarily when the turbidity is relatively low its removal will be incidental to the softening treatment. At such times the order of operations will be to apply the lime in the first pre-mixer, thence pass successively through the first mixing or reaction tank, the first clarifier, the lower section of the bypass conduit in which it will be given CO_2 and returned to pre-mixer No. 2 for the alum dosage before passing through the second reaction chamber and the plain settling basin. It will then be recarbonated and pass to the filters.

At times of high turbidity the order of application of chemicals will be reversed so as to precipitate out the turbidity before softening. The water then will first be dosed with alum, then flow from the first pre-mixer to the first mechanically stirred reaction basin, and thence

to the first clarifier where the turbidity will be largely removed. The settled water will then return so the second pre-mixing tank for its lime dosage, thence to the second settling basin followed by recarbonation before going to the filters.

Series operation will be the normal operation on account of the practicability of using returned sludge from the first basin and thus securing somewhat better softening operations. Preliminary operations indicate a marked reduction in hardness by series over parallel operation. Operations to date have produced a water with about $3\frac{1}{3}$ grains hardness and with but 2 grains of carbonate hardness remaining. Lime alone has been used for softening with clarification assisted by feeding $\frac{1}{2}$ grain of alum.

Carbonation

The water is recarbonated using CO_2 generated by an oil burner under a boiler. The boiler is cross-connected with the heating system so that the heat generated will be used in heating the buildings during the winter months. During the summer, the steam generated will necessarily be wasted.

The gasses from combustion pass through a scrubber for cleansing and cooling and are then compressed under approximately 12 feet head of water and discharged through a galvanized pipe grillage located in the bottom of the carbonating basin. The carbonating basin has a detention capacity of 20 minutes at the rated capacity of the plant. The CO_2 piping laterals are $\frac{3}{4}$ inch in diameter and have $\frac{1}{16}$ inch holes spaced at 24 inch centers.

Filters

After carbonation, the water passes to the mechanical gravity filters. The filters are in four units each of 3 m.g.d. at standard water works rating of 2 gallons per square foot per minute. Each filter bed is in effect two filters, separated by a central gullet, the upper part of which takes the dirty wash water and the lower part being the effluent channel and the wash water distributer. The filters contain 30 inches of sand specified as having an effective size of 0.36 to 0.55 mm. and a uniformity coefficient of 1.3 and 1.6. The sand overlies a gravel bed of a total depth of 21 inches over the center line of the laterals. The gravel is placed in four carefully graded layers.

Each filter has four 9- by 12-inch C. I. headers, each feeding 52 2-inch C. I. laterals having $\frac{3}{8}$-inch holes 6-inch centers.

The pipe gallery is commodious and piping so arranged as to provide ample walkways and room for removal or repairs of equipment. All valves are hydraulically operated and provided with cast iron bronze lined cylinders. The main influent channel and the sewer are of reinforced concrete. All other conduits in the pipe gallery are of cast iron. The filter equipment was installed by the International

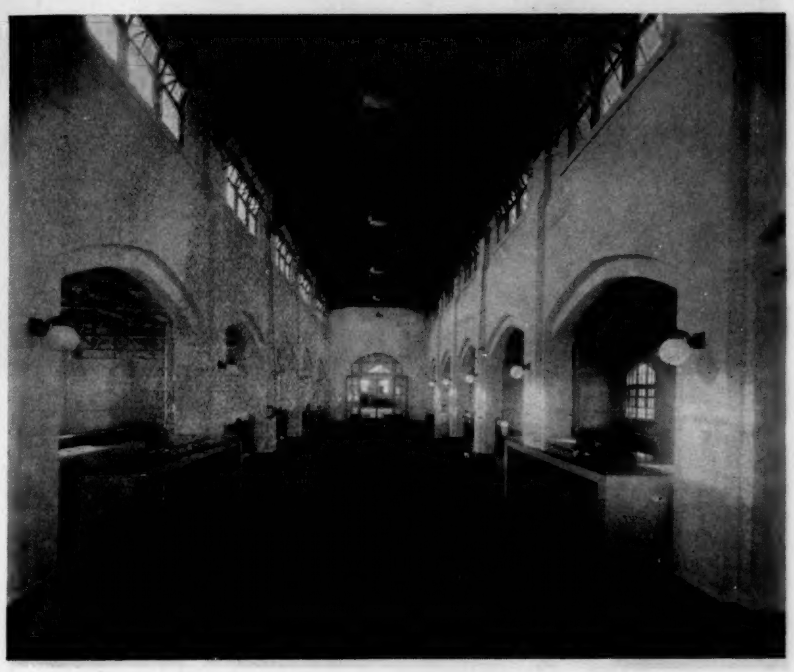

FIG. 5. FILTER OPERATING GALLERY

Filter Company of Chicago, who also installed the pumping equipment, piping inside the station, mechanical agitators, etc.

The filters discharge into a clear well directly underneath, having a capacity of 600,000 gallons. The clear well is in effect a two compartment suction reservoir for the high lift pumping equipment, which discharges directly into the distribution system on which floats an elevated storage reservoir of 8 million gallons capacity advantageously located in the City.

High lift pumping equipment

The high lift pumping equipment consists of 3 units as follows:

1–4.5 m.g.d. combined electric and gasoline engine unit
1–7.5 m.g.d. electric motor centrifugal unit
1–10.0 m.g.d. electric motor centrifugal unit

The pumps take suction directly from an open channel running under the pump room floor and connecting directly to each of the two

FIG. 6. HIGH LIFT PUMP ROOM

compartments into which the clear well is subdivided. All motors throughout the plant are of the synchronous type. All pumping equipment was furnished by the American Well Works of Aurora, Illinois. Control equipment is Westinghouse with all installation wiring etc. by the Robertson Electric Company of Cedar Rapids. The gasoline engine units are driven by Sterling high speed gas engines with rating established at not to exceed 1250 r.p.m.

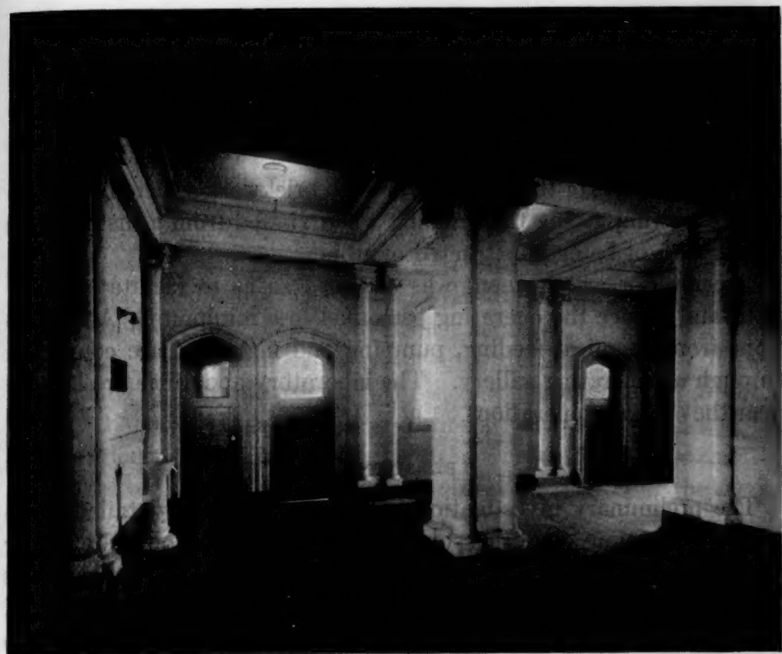

FIG. 7. MAIN ENTRANCE LOBBY

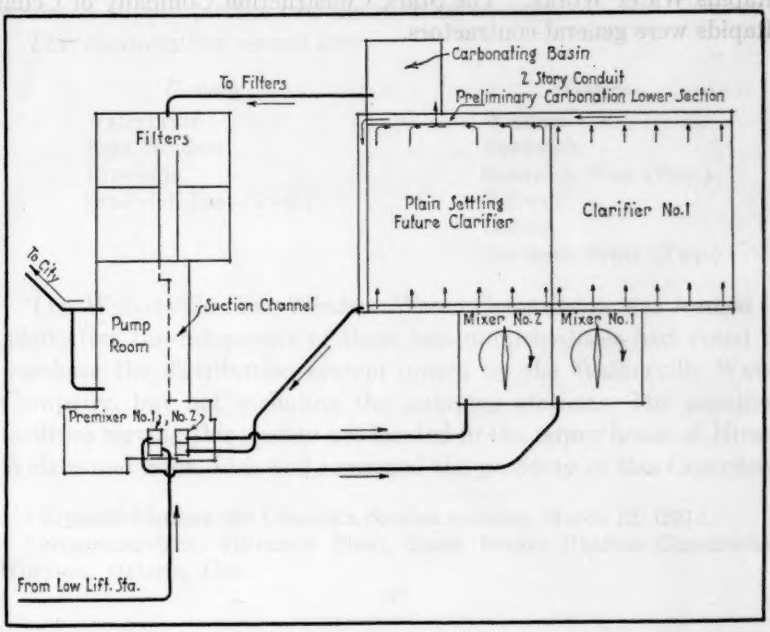

FIG. 8. FLOW OF WATER IN SERIES OPERATION. CEDAR RAPIDS SOFTENING PLANT

Wash water tank

Wash water for the filters is secured from a 100,000 gallon wash water tank located in the tower of the building.

The building

The building is of the Gothic type with brickwork selected to match the stone trim, giving the building when viewed from a distance the appearance of being constructed of stone.

The interior arrangement was designed so as to facilitate operations and reduce the operating personnel to a minimum. All operations from chemical feeding, pumping and filtration, are connected through an operating gallery. The laboratory and office are located near the center of operations.

PERSONNEL

The preliminary investigations, the preparation of detailed plans and specifications and the supervision of construction were under the direction of Alvord, Burdick and Howson, Consulting Engineers of Chicago. The Engineers associated with them Mr. Victor A. Matteson as architect and Mr. Charles P. Hoover of Columbus, Ohio as consulting chemist. The pipe lines and certain exterior work were executed by Mr. H. F. Blomquist, Superintendent of the Cedar Rapids Water Works. The Stark Construction Company of Cedar Rapids were general contractors.

THE WATER SUPPLY OF THE ESSEX BORDER DISTRICT[1]

By G. Hudson Strickland[2]

From small villages and settlements, entirely independent of each other, taking their supplies of water from the village wells or drawing it from the Detroit River, as convenience arranged, the Border Municipalities have grown, until today we have the Essex Border District comprising ten municipalities with a total population of approximately 120,000 people served by a modern filtration plant and two distribution pumping stations which feed a network of approximately 250 miles of mains which reach out into every section of these communities.

These cities, towns and townships are situated along the Detroit River and those of the Eastern or up-river section are served by the Walkerville and East Windsor Water Commission. The downstream or Western section is served by the Windsor Water Commission. The filtration plant, which is jointly owned by these communities, is operated by the Essex Border Utilities Commission and serves as a common supply for the two distribution systems.

The communities served are:

Eastern	*Western*
Walkerville	Windsor
East Windsor	Sandwich
Riverside	Sandwich West (Twp.)
Sandwich East (Twp.)	Ojibway
	LaSalle
	Sandwich South (Twp.)

The Walkerville-East Windsor Water Commission was formed in 1930 after the ratepayers of these two municipalities had voted to purchase the distribution system owned by the Walkerville Water Company, but not including the pumping station. The pumping facilities serving this system are located in the power house of Hiram Walker and Sons, Ltd. and remained the property of this Company.

[1] Presented before the Canadian Section meeting, March 12, 1931.

[2] Superintendent, Filtration Plant, Essex Border Utilities Commission, Windsow, Ontario, Can.

The capacity of this station is 16 m.g.d., one-half of which is powered by steam. The balance is driven by electricity which is steam generated within the power house of this Company. A normal working pressure of 65 pounds per square inch is maintained at the station. The pressure is increased to 100 pounds per square inch for fire purposes, and is raised to 110 pounds per square inch on receipt of the second fire alarm. All water rates in the Eastern District are collected by this commission and the charges are based upon the following schedule:

General rate—6.8 cents per 100 cubic feet.

Minimum meter service charges from $9.00 for $\frac{5}{8}$-inch service to $124.00 for 6-inch service.

Service charge of 9 cents per foot frontage.

All charges except assessments on vacant property collected quarterly.

The Windsor Water Commission was formed in 1889 to serve the Town of Windsor with a population of 10,058. Today it serves with its pumping station the City of Windsor and five other communities. The total rated pumping capacity of this station is:

	m.g.d.
Electric motor driven	24
Steam driven	25
Total available at one time	37

Note: One 12 m.g.d. pump may be driven either by steam turbine or electric motor.

A normal pressure of 60 pounds per square inch is maintained at this station.

Water rates in the Western District are collected by the Water Commissions of the governing bodies of the various communities served. The City of Windsor receives compensation for the pumping services tendered the other municipalities in this district from the Essex Border Utilizies Commission. Each charge is based upon the total consumption of the municipality as shown by a series of master meters located on the main distribution lines serving the district.

Metered water rates in the City of Windsor are:

General rate—6 cents per 100 cubic feet.

Service charge—3 cents per foot frontage per quarter.

Fire protection charge—$\frac{1}{4}$ Mill of assessed value per quarter.

Meter rental from 80 cents per quarter for $\frac{5}{8}$-inch meter to $60.00 per quarter for 8-inch meter.

Charges are billed quarterly and a 10 percent discount is allowed for prompt payment.

The final chlorination of the water supplies of the two Districts is at the distribution pumping stations, where dosages are applied under the control of the Local Board of Health.

TABLE 1

YEAR	POPULATION	DAILY CONSUMPTION	PER CAPITA
Eastern District			
		m.g.d.	*g.p.d.*
1916	9,749	2.35	241
1917	10,625	2.91	274
1918	11,050	3.10	280
1919	11,417	2.70	236
1920	13,651	2.89	212
1921	15,489	2.97	192
1922	16,086	3.38	210
1923	19,222	3.50	182
1924	21,262	3.96	186
1925	23,984	3.42	145
1926	26,864	2.95	110
1927	28,122	2.71	96
1928	30,351	2.72	90
1929	32,472	3.16	92
1930	31,000	3.19	103 (Approx.)
Western District			
1916	30,645	7.14	233
1917	32,161	8.19	254
1918	33,690	8.01	238
1919	36,291	8.03	221
1920	42,393	8.63	204
1921	45,026	9.00	200
1922	47,477	9.33	197
1923	53,578	9.90	185
1924	59,924	10.16	170
1925	64,510	10.61	156
1926	71,291	9.85	138
1927	79,895	8.84	110
1928	82,768	8.64	109
1929	86,045	9.24	107
1930	84,000	8.54	102 (Approx.)

The growth of population in the two water districts, the average daily consumption and the per capita use of water during the past 15 years are shown in table 1.

A study of table 1 shows that there has been a steady growth of population and a progressive decrease in the per capita use of water during this period. The effectiveness of metering as reflected in the per capita consumption is shown in 1926 in the Eastern District and is followed a year later in the Western District. These major reductions may be credited to the waste water survey conducted in the City of Windsor and to the general policies of metering inaugurated at this time. In 1926 but 50 percent of the services in the Eastern District were metered. By December, 1930 this has been increased to 90 percent. Up to 1926 the City of Windsor had installed only 59 meters, by December, 1930 this number had been increased to 12,400 which represents 90 percent of the total services. The remaining communities in the Western District are following a similar aggressive metering program and by 1935 the whole of the District will be completely metered.

TREATMENT OF WATER

Early in 1924 the Essex Border Utilities Commission began construction of the present filtration plant and intake and in May, 1926 these were placed in operation to serve the entire Essex Border District. The old intakes are maintained in operating condition and serve as the sources of emergency supplies to be used in the event of a major interruption to the service from the filtration plant.

Raw water is taken from the Detroit River through a 4-foot diameter steel intake pipe which extents into the river approximately 600 feet from the shore line. A 5- by 4-foot elliptical reinforced concrete tunnel connects the intake pipe with the receiving well of the low lift pumping station. From the receiving well the water passes through revolving screens, two meshes to the inch, before entering the suction wells.

The forming of frazil ice at the bellmouth of the intake represents the only operating difficulty which has been experienced with this part of the filtration plant. On several occasions sufficient ice has formed to block the flow of water into the receiving well and relief has been secured through a feature in the design of the low lift pumping station which permits the discharge from the low lift pumps to be directed back into the intake exerting a pressure on the ice formed at the mouth. Temporary relief, sufficient to permit the immediate return of the plant to normal operation, has been secured in this way and permanent relief has always followed when the presence of sun-

light or an increase in air temperature has changed the water temperature sufficient to break the bond between the ice and the steel intake.

During the past two winters frazil ice has not appeared in quantities to cause inconvenience and it is the author's opinion that the ice coating which formed and remained over Lake St. Clair and the upper part of the Detroit River prevented the super cooling of the water through agitation and radiation which is essential to the forming of this ice when other factors are favorable. It has been observed that the following conditions prevail when frazil ice trouble develops; a clear night sky, winds sufficient to agitate the surface of the water, air temperatures below 15°F. and the upper Detroit River and lower Lake St. Clair comparatively free from surface ice.

Three low lift pumps with rated capacities of 7, 14 and 21 millions of Imperial gallons per 24 hours raise the water from the suction wells to the level maintained in the coagulation basins, a height of 38 feet, from where it flows by gravity to the Filter Building, thence to the clear wells and reservoir. The storage capacity in the clear wells and reservoir is 2,300,000 gallons.

A riveted steel main 42 inches in diameter carries the water to Walkerville where a 24-inch main branches off to the pumping station of Hiram Walker & Sons, Ltd. A 36-inch main of like design continues from this junction point to a flow regulating chamber located adjacent to the pumping station of the Windsor Water Commission. This chamber is designed to regulate the flow of water into the open suction wells of this pumping station and to prevent the flooding of that station in the event of a sudden shutting off of their pumps.

Chemical treatment

In the past four years turbidities ranging from 3 to 8 p.p.m. have been observed in the raw water supply to the filtration plant. The appearance of turbidity is seasonal and the data in table 2 represents a typical year.

The range of types of turbidity is from extremely fine, light semi-colloidal particles to very coarse and heavy bits, the former requiring relatively heavy dosages of chemicals to permit efficient coagulation, while the latter will settle out with the addition of very small dosages of alum. The common experience in this plant during the highly turbid seasons is to have a mixed turbidity requiring the constant adjustment of chemical dosages to permit a proper and economical treatment.

The coagulants are fed through two dry-feed machines and enter the raw water in the low lift pumping station receiving well. Mixing takes place in the suction wells, the low lift pumps and discharge conduit and in two "over and under" type mixing chambers operated in parallel. The total time of mixing, when the plant is operating at its rated maximum capacity is 4.6 minutes.

The theoretical time of retention of the water in the coagulation basins is 1 hour and 20 minutes, when the plant is operating at its maximum rated capacity, but observations made in the past year indicate that certain currents are created when the flow is at this rate and water has been known to pass thrugh the basins in approximately

TABLE 2

Turbidity, Detroit River, Canadian Shore, 1929

TURBIDITY, BETWEEN	NUMBER OF DAYS												
	January	February	March	April	May	June	July	August	September	October	November	December	Total
p.p.m.													
0– 10	19	26	5		2	3	6	11	5	2		13	92
11– 20	4		14		1	18	21	15	15	12	5	7	112
21– 50	6	2	10	3	4	6	3	5	10	8	20	9	86
51–100	2		2	5	7	2	1			8	5	1	33
101–200				11	10	1				1		1	24
201–400				11	7								18

Maximum turbidity, April 11, when 800 p.p.m. was observed at 2 p.m. and 3 p.m.

45 minutes. Another observation made in 1930 indicates that mixing continues in the first quarter of the coagulation basins and that the point of maximum settling is in the second quarter. The former conclusion was drawn from the fact that a very decided agglomeration of the floc particles occurs in the first quarter and the latter was reached by measurements made of the settled sludge.

Previous to 1930 the basins were cleaned twice yearly, the first cleaning early in January following the autumn and early winter turbidity and the second cleaning in July following the spring and early summer run of turbidity. Sludge to a maximum depth of 8.5 feet was noted in July, 1929 and it was decided to change the cleaning times to prevent these excessive deposits which must affect the set-

tling efficiency of the basins. The basins were cleaned in January, May and July, 1930 and the maximum depth of sludge noted was 4.5 feet. Hard packed deposits have been observed on the floor of the basins at each cleaning and the uniformity of their location and size indicate that certain definite eddying currents prevail as the water flows through.

In 1926 and 1927 sulphate of alumina was the only chemical used as a coagulant. In 1928 and 1929, ferrous sulphate and hydrated lime were introduced in May, June and July in an effort to build up a larger precipitate than that which forms with sulphate of alumina and so throw down into the settling basin a greater percentage of the algae which appear in these months in their maximum numbers.

During this so called "algae period" in 1927 filter runs as low as 1 hour and 20 minutes obtained and the average length of run for June was less than 6 hours. The minimum average in 1928 was 12 hours and in 1929 this was held to 10 hours. Estimating the daily consumption during these months and recognizing that two frequent backwashing of the filter beds must seriously affect the physical and bacteriological quality of the filter effluent it was felt that a minimum run of 10 hours was necessary to ensure efficient operation. Lime and iron dosages ranging from 2.4 and 1.8 to 2.0 and 1.0 g.p.g., respectively, were used to secure these results.

Previous to May, 1930, "alum" dosages ranged from a minimum of 0.5 to a maximum of 5.0 g.p.g., the quantity fed being controlled by the type and quantity of turbidity appearing in the raw water. A maximum turbidity of 30 p.p.m. is permitted in the water applied to the filters as it has been observed that unsatisfactory effluents generally follow if the applied water has more than 30 p.p.m. of turbidity. The physical characteristics of the floc observed in the settling basins and filter beds act as a factor in determining the proper dosage.

Prechlorination

The chlorination of the water, prior to filtration, was given serious thought early in 1930 and it was decided that a full scale experimental program would be conducted in this plant for a period of at least six months. This program was started May 2 and continued into 1931.

Chlorine was applied during this period at a rate of 1.5 pounds per million gallons of water. This dosage has proven to be sufficient to

maintain a residual of not more than 0.02 p.p.m. in the water applied to the filters. The average residual noted at the entry to the coagulation basins was 0.04 p.p.m. The point of application of the chlorine is in the low lift pump discharge conduit and is approximately midway in the total mixing period.

A peculiarity of the function of chlorine is the type of floc formed. Typical alum floc observed here previous to May, 1930 was a spongy, irregular, disc shaped mass ranging in size from a "pin point" to a maximum diameter of $\frac{1}{16}$-inch. With chlorine applied, this floc as it passes into the coagulation basins, is fine and hair-like in shape and these hair-like particles agglomerate in the first quarter of the coagulation basins to form large stringy masses which settle rapidly. Masses as large as 1 inch in length and $\frac{1}{16}$-inch in diameter have been observed. The size varies and there appears to be some relationship between the number of plankton present, the temperature of the water and the size of the particles. Further observations along this line will be made in 1931 to aid in a confirmation or a denial of this thought. Under the microscope the floc appears to be heavily loaded with living plankton, so situated in the mass that one might conclude that they had been entrained by the floc as it formed. It has been noted, also, that turbidities of 30 to 50 p.p.m. tend to retard the action of the chlorine and with 50 p.p.m. or more present, little, if any, benefit other than its value as a bactericide is derived from the use of chlorine. A brief summary of the results obtained during this period may be expressed as:

(a) Coagulant costs reduced to approximately 50 percent of 1928 and 1929 costs.

(b) Filter runs increased approximately 30 percent, with corresponding reductions in wash water use and "lost" filter hours.

(c) An effluent well within the U.S.P.H.S. Standard at all times.

(d) Decidedly cleaner conduits, walls, troughs and filter sand.

Filters

The ten filters are inspected at regular intervals and every effort is made to maintain these beds in as clean a condition as plant facilities permit. Sand shrinkage from the filter walls and the cracking of the filter mat are not important problems of this plant. The former condition prevails and a maximum shrinkage $\frac{3}{4}$ inch in width and 4 inches in depth has been observed, the average is approxi-

mately 50 percent of this. Cracking of the filter mat has not been observed at any time. Mud balls have appeared on occasion, although one might more suitably describe them as small soft clay accretions which can be removed with slight increases in the length of time of the filter backwash.

A rounded sand, regular in shape and consistent in quality, having an effective size of 0.46 mm. and a uniformity coefficient of 1.4 was employed in the construction of the filter mat. In the first three years of service this sand acquired a coating. The following table records the percentage of coating by weight on the filter sand grains:

Average of ten filters, September, 1929

INCHES SAND	PERCENT COATING
Top ½	10.95
½ to 2	7.99
2 to 6	4.53
6 to 12	2.85
Below 12	1.48

Early this year additional filter sand, having an effective size of 0.5 mm. and a uniformity coefficient of 1.38, was purchased. The sand from two of the filters has been placed in the remaining 8 beds and the new sand was used to rebuild the first two units. The average freeboard is now 24 inches and the average depth of sand 38 inches. It is anticipated that the change of freeboard from 31 to 24 inches will affect the backwashing of the filters to permit an efficient wash with less water and in a shorter time. The change to a slightly larger sand was decided upon after observations made indicated that the water applied to the filters carried sufficient floc to quickly form a coagulum mat. It is expected that the larger size sand will permit a longer average filter run and maintain the present standard physically and bacteriologically.

Filter rates have ranged from 95 to 129 million imperial gallons per acre per day, the rate being determined by the demand made upon the plant. The general policy is to maintain a rate which will permit all beds to be in service during the peak hours of every week day. Changes are seasonal, the lower rates prevailing in the spring and autumn, the medium rates in the winter months and the maximum rates have proven sufficient to meet the demand during the peak sum-

mer days. The maximum rate which may be employed without affecting adversely the general qualities of the effluent has not been determined.

Laboratory control

A small laboratory is maintained and routine bacterial analysis, in addition to the standard turbidity observations, are made. Samples of raw and filtered water are collected five times daily, and these are examined, using the technique and media as recommended in "Standard Methods—Partially Confirmed Test." The results are expressed in terms of the most probable number of B. coli-aerogenes per 100 cc. of water. Counts are made at least three times each week and daily during the months of May, June and July to determine the plankton content of the raw water. Observations are made at a magnification of 210x and are recorded as follows:

> "All single cell algae, as one unit; the filamentous algae, as one unit per 100 micra of length; each frustule of diatoms, as one unit: individual flagellates, as one unit: flagellates appearing as colonies—according to the number in the colony."

The following texts are used for reference:

(a) The British Fresh Water Algae, by West and Fritsch.

(b) The Microscopy of Drinking Water, by G. C. Whipple (Revised edition)

(c) Phyto Plankton of the Inland Lakes of Wisconsin, appearing as bulletin No. 57 from the Wisconsin Geological and Natural History Survey.

Observations are made and recorded on the day sheets each hour in the low lift pumping station and filter building. These are studied and averages taken and built into a monthly summary. The reports of each month are assembled into an annual report. Indicating, recording and integrating gages and meters are maintained on the low lift and backwash water pump discharges. Each filter operating table has an indicating and recording loss of head gage and an indicating and integrating rate of flow meter. All gages and meters are kept in operating condition and the records taken are used as a check on the operating efficiency of these units. Every effort is made to insure knowledge of, if not control over, every operation attempted.

The results obtained in the laboratory are arranged daily, summarized each month and assembled into the general annual report.

Copies of the monthly summaries are forwarded to the Ontario Department of Health.

A plant diary provides a permanent record of unusual events and occurrences.

TABLE 3

Operating cost data

YEAR	M.G. FILTERED WATER	TOTAL COSTS PER M.G.
1926	3,108.33 (part year)	$40,679.63 = $13.09
1927	4,183.72	51,779.27 = 12.38
1928	4,158.70	54,537.56 = 13.10
1929	4,448.45	60,094.70 = 13.50

	1928	1929
Coagulants	$2.18* 16.7**	$2.37 17.6
Power	$2.86 22.0	$2.84 21.0
Wages	$4.47 34.1	$4.49 33.2
Overhead, taxes, insurance and grants	$1.25 9.5	$1.86 13.8
Maintenance—plant, building, grounds, general charges	$2.34 17.7	$1.94 14.6
Total charges	$13.10	$13.50

* Per million gallons.

** Percent of total.

GENERAL DATA

Capital costs are borne by the municipalities comprising the Essex Border Utilities Commission and the apportionment is based upon the estimated use of water in each municipality. The apportionment as at December 31, 1930 was fixed January 20th, 1927 by the Ontario Railway and Municipal Board, to whom all appeals for revision, which cannot be agreed upon by the municipalities, are taken for final adjustment. Such appeals may be made each year.

Operating costs for the five years 1926 to 1930 inclusive are given in Table 3.

The operating staff of the filtration plant includes a superintendent, a chief operating engineer, a chief filter operator, three operating engineers and two filter operators and a general utility man.

We may be justly proud of the purity, the clarity and the general attractiveness of the water supply of the Essex Border District. It represents the contribution that the water commissions and the Essex Border Utilities Commission are making to the welfare of these municipalities. This supply is, in some fair measure, the controlled product of an efficiently operated supply system which meets the technical demand of the chemist, the sanitary demand of the doctor and the aesthetic tastes of a discerning public.

PERFORMANCE OF SMALL TURBO CENTRIFUGAL UNITS[1]

By S. A. Thompson[2] and Frank Lawlor[3]

The steam turbine has long held a place as an important prime mover for waterworks pump service. The high duties obtainable with turbine units from 10 to 100 million gallon capacity, are generally known and appreciated.

Economies in first cost, upkeep and flexibility through speed adjustment as well as operating reliability, are all characteristics associated with these larger units.

Less known are the developments in the field of smaller units. Until relatively recently the small turbine unit has been lacking in many of the respects which characterize the larger machines.

In recent years, not to say months, considerable development has been made in these smaller sizes.

The pump efficiencies have been materially boosted by important improvements in design and the steam turbine performance has been bettered through careful proportioning of frames to correspond best with capacities and through great refinements in nozzle and bucket design and construction.

At Burlington, Iowa, in the plant of the Citizens Water Company, we recently had occasion to familiarize ourselves with these developments when we purchased and installed two new pumping units.

Before installing the turbine units, we had in our plant three large reciprocating engine units of 6 million gallons each, which were used to deliver the water to the city mains. We also had one 6 million gallon low lift pump and two belted engine-driven units of 3 million gallons capacity each.

The Underwriters required the installation of an additional 5 million gallon unit to provide additional spare capacity. Inasmuch as this size was somewhat removed from our average operating conditions, we selected a 3 million gallon and a 3½ million gallon unit as

[1] Presented before the Missouri Valley Section meeting, October 31, 1931.

[2] Chief Engineer, Citizens Water Company, Burlington, Ia.

[3] Superintendent, Citizens Water Company, Burlington, Ia.

being the better size for us and which would still meet the requirements of the Underwriters.

These particular units take the water from the Mississippi River and discharge it into our filter tanks with a total pumping head of 50 feet. The water horsepower consequently at $3\frac{1}{2}$ million gallons would only be 30.7 and the water horsepower at 3 million gallons only 26.3.

We received bids from a number of turbine and pump manufacturers and finally selected two units offered by the Murray Iron Works Company, these machines having the best steam performance and comparing favorably from a price standpoint.

These units were installed about three months ago and have been in practically continuous operation since that time.

The two turbines are of the impulse type and have one 2-row element in the first stage followed by three single row pressure stages. The normal operating speed is 3800 r.p.m., which speed was recommended by the manufacturers as a conservative figure and conducive to trouble-free operation, as compared with speeds of 6000 r.p.m. and over offered by some of the competitors, who by using this higher speed are able to employ a smaller turbine frame. We looked favorably on this lower speed, especially as we wanted a pump designed for an excess capacity for emergency, which necessarily meant an increase above the normal operating speed.

The turbines are equipped with constant speed, oil relay governors. These are, however, set high and normally the speed is governed by float regulators in the discharge reservoir. These float regulators actuate the same oil relay mechanism through a sylphon arrangement consisting of two bellows with a hermetically-sealed tube connecting them, filled with a non-compressible fluid. One of these bellows is located on the float valve in the tank and the other on the oil relay governor arm of the turbine.

The turbines are equipped with all machined, stainless steel nozzles and all machined, monel metal blading, conducive to long life and sustained economy. They have carbon packing and steam seals on the shaft glands.

The turbines are connected to the pump through herringbone reduction gears which reduce the speed to 1800 r.p.m. We chose this operating speed with a view of providing a somewhat better mixing of our alum than was possible with lower operating speeds.

The pumps used on these units were manufactured by the Ameri-

can Well Works, Aurora, Illinois. They have a 12-inch suction and a 12-inch discharge, are balanced for end thrust and were especially designed for our condition of low head to give the maximum efficiency.

The condenser furnished is of the waterworks type, also manufactured by the Murray Iron Works Company, and both of the turbines are served by one condenser. This has 500 square foot total surface.

GUARANTEES AND TESTS ON PUMPING UNITS

The guarantees on the pumping units were as follows:

On the 3 million gallon unit a duty of 70½ million foot pounds per 1000 pounds of steam. On the 3½ million gallon unit a duty of 71 million foot pounds per 1000 pounds of steam.

These figures we considered satisfactory when considering the very small horsepower of the unit and the fact that our steam conditions are not conducive to high economies, our steam pressure being 140 pounds without any superheat.

In the performance test, which will be described, the duty guarantees made by the manufacturer were substantially improved.

The tests were conducted at normal load on each unit as well as at 4 million gallon capacity on the large unit and 3½ million gallon capacity on the small unit. Readings were also taken at reduced capacity.

Our steam conditions remained about constant during the test at 140 pounds pressure and approximate 0.45 percent moisture in the steam. The vacuum was maintained at about 28½ inches.

The tests lasted in all several days. The final tests were run with a duration of two hours for each point.

The final data on the 3½ million gallon unit are shown in table 1.

Similar data on the 3 million gallon unit are given in table 2.

At increased capacities the figures were as shown in table 3.

For decreased capacity the results obtained are shown in table 4.

For the two units running together at slightly reduced capacity, the readings are given in table 5.

It will be apparent from these figures that the turbine unit met the economy guarantees with from 10 to 12 percent margin on every point. In fact, at reduced capacity the 3½ million gallon unit exceeded this guarantee by nearly 17 percent.

After running the tests we made certain comparisons with larger units and have estimated the performance which could be reasonably expected with changed steam conditions.

TABLE 1

Test data on 3½ m.g.d. unit

Rate of pumpage	3,525,000 gallons per day
Suction, per mercury column	14.5 inches
Discharge pressure	14.358 pounds
Total dynamic head	49.581 feet
Total condensate weighed	1,651.5 pounds
Net condensate, correct for moisture	1,636.64 pounds
Duty, in foot pounds, per thousand pounds dry steam	78,870,000

TABLE 2

Test data on 3 m.g.d. unit

Rate of pumpage	3,010,900 gallons per day
Suction, per mercury column	14.75 inches
Discharge pressure	14.258 pounds
Total dynamic head	49.633 feet
Total condensate weighed	1,446.5 pounds
Net condensate, corrected for moisture	1,433.48 pounds
Duty, in foot pounds, per thousand pounds dry steam	77,091,590

TABLE 3

Test data for the 3½ million gallon unit at increased capacity:	
Rate of pumpage	3,950,000 gallons per day
Suction, per mercury column	14.25 inches
Discharge pressure	14.358 pounds
Total dynamic head	49,298 feet
Total condensate weighed	1,821.5 pounds
Net condensate, corrected for moisture	1,805.1 pounds
Duty, in foot pounds, per thousand pounds dry steam	78,400,000
For the 3 million gallon unit:	
Rate of pumpage	3,431,000 gallons per day
Suction, per mercury column	15.53 inches
Discharge pressure	14.508 pounds
Total dynamic head	51.1 feet
Total condensate	827 pounds
Net condensate corrected for moisture	820.4 pounds
Duty, in foot pounds, per thousand pounds dry steam	79,000,000

These turbines are built so as to be capable of future operation with 250 pounds pressure.

If we should at some future time make a change in our boiler layout and install high pressure boilers with 250 pounds pressure and 200° superheat, these machines would give a duty on the average of

TABLE 4

Test data for the 3½ million gallon unit at decreased capacity:	
Rate of pumpage	2,619,200 gallons per day
Suction, per mercury column	14.125 inches
Discharge pressure	14.108 pounds
Total dynamic head	48.58 feet
Total condensate	567 pounds
Net condensate corrected for moisture	563 pounds
Duty, in foot pounds, per thousand pounds dry steam	82,800,000
For the 3 million gallon unit:	
Rate of pumpage	2,090,400 gallons per day
Suction, per mercury column	14.5 inches
Discharge pressure	13.688 pounds
Total dynamic head	48.033 feet
Total condensate weighed	554.5 pounds
Net condensate corrected for moisture	550.1 pounds
Duty, in foot pounds, per thousand pounds dry steam	69,000,000

TABLE 5

Rate of pumpage	6,152,000 gallons per day
Suction, per mercury column, average	16.937 inches
Discharge pressure, average	16.108 pounds
Total dynamic head, average	55.874 feet
Total condensate	1,581.00 pounds
Net condensate corrected for moisture	1,566.80 pounds
Duty, in foot pounds, per thousand pounds dry steam	77,900,000

about 106 million food pounds per 1000 pounds of steam, which we believe is quite remarkable when considering that the water horsepower is between 20 and 30 on the smaller machine and only slightly over 30 on the larger unit.

It would appear from our experience that turbine-driven pump

units in small capacities can be constructed, which will provide economies in steam performance which compare reasonably well with other types of units.

From a mechanical standpoint the service obtainable from these turbine units is in many respects superior to other types of units. Such mechanical performance, however, to our way of thinking, presupposes conservatism in way of speeds and automatic forced lubrication and high grade materials in all the parts which come in contact with the steam flow so as to eliminate erosive and corrosive action.

UNDERGROUND WATER SUPPLIES OF REGINA[1]

By R. O. Wynne-Roberts[2]

Sources of adequate underground supplies of water are usually found first by studying the geological formations and then by drilling test wells. Where water-bearing strata have been located over great areas by the sinking of wells the prospect of success is practically assured, provided that the limit of yield is not near exhaustion. For example, Howard E. Simpson of North Dakota, in a report prepared by him, stated that, "in general the Dakota sandstone is one of the most important aquifers in North America and in fact in the world. It supplies 20,000 flowing wells in the States of North Dakota, South Dakota, Minnesota, Iowa and Nebraska." This formation extends into Saskatchewan near Moose Jaw at enormous depth, yielding little water of poor quality. There are some locations in Canada where satisfactory underground sources extend over considerable areas. In places like these the problem of obtaining water is not a serious one, but if such locations are not known, and necessity calls for exploration, it then becomes one of some complexity. Instances are known where well drilling in an area has proved to be abortive, but when the operations were transferred a short distance away in the same neighborhood, abundant supplies were found. There are places, however, where water-bearing strata do not exist, but well sinking has there been repeated at great expense and with depressing results. In cases like this the authorities have to go further afield for supplies of water, and a study of the local geology and the contour maps of a particular locality will assist in the judgment as to where best to sink a well.

The author was requested by a small western municipal authority to advise on how best to obtain water. A well had previously been sunk in the center of the town and it proved unproductive. After studying the locality he recommended sinking a well about a quarter of a mile from the sterile one. The members of the Council were

[1] Presented before the Canadian Section meeting, March 12, 1931.

[2] Consulting Engineer, Toronto, Ontario, Can.

skeptical, paid the account, and decided to take no further action. But something had to be done, and a few months later a steel cased well was drilled at the spot indicated and to the depth prescribed, and an abundant supply of good water was obtained. The first well was in a bank of clay and the successful one was in a glacial gravel deposit.

The City of Regina in 1911 had a population of about 30,000, but the supply of water was inadequate, which the Water Works Department had endeavoured in different ways to remedy. In that year the author was instructed to investigate the possibility of augmenting the supply of water. Authentic information as to the geological formations was then practically non-existent, the map was inaccurate and without contour lines. The first task was to make a comprehensive study of the geology and to correct the map.

The geological formation of the district was outlined by the author and this was confirmed nearly twenty years later in a comprehensive report by professional geologists. The geological formation of the country around Regina is largely the result of a number of ice invasions. Huge sheets of ice of great thickness moved from the vicinity of Hudson Bay across the country into the United States. Each of them often picked up hard boulders which, as the ice sheets moved slowly to the south, helped to level and change the original features of the country. When one ice sheet eventually melted back, at the same time depositing its debris, another sheet in a later period passed over the land, again changing its topography, and so on, until the last invasion took place and the ice finally receded to the north and left behind it mud which formed the plains, boulders etc., which built the moraines, and behind them were piled up gravel, sand and clay. Great lakes were formed by the damming up of the ice in its recession and these contributed to the rebuilding of the land, leaving the country in the condition we know it.

A few abbreviated extracts from Prof. Simpson's report of 1930 will bring our knowledge up to date.

"The Glacial Lake Regina Clay is very sticky and tenacious in character when wet, but falls to pieces as it dries, forming a granular mass. The clay is often referred to as 'gumbo.'

"The thickness of this formation at Regina is approximately 40 feet. Greater thicknesses probably occur at other points beneath the plain, especially to the westward near its axis.

"The Glacial Drift beneath the Regina clay and elsewhere at the surface covering the bedrock over the entire area of the region is composed of a mixture of clay, sand and gravel with occasional boulders of sand or gravel or both.

"The thickness of the drift is very variable, but in general it is from 30 to 40 feet under the more level plains, and 100 to 200 feet in the heavier topography of the morainal ridges.

"A consideration of the problems connected with the study of a ground water supply for Regina becomes chiefly a study of the waters of the glacial drift. Exposed sections of the drift are few and superficial, therefore a study of well records is of the highest importance. This has been supplemented by careful field observation and study of all evidences of the natural recovery of ground waters including seepage, springs, and the flow of surface streams in dry weather.

"Gravel and sand are frequently found in layers, lenses, or irregular shaped bodies, within the boulder clay, but much thicker and more wide-spread deposits of these are found in places at the base of the drift immediately overlying bedrock and between the layers of boulder clay laid down by different advances of the ice. There were undoubtedly two, and probably more, advances in this region. These deposits are capable of acting as reservoirs holding water, in large amounts, in the open spaces between the grains of sand and gravel, which is rendered available for use at the surface by means of wells.

"The chemical quality of this water though hard, especially in temporary hardness, is generally good since it is the nearest of all ground water to its original source, the rainfall, and since it is generally in slow motion through this coarse material, it has not gathered much mineral matter from the relatively insoluble gravel and sand."

Although the Province of Saskatchewan is relatively a flat country a study of a contour map will show that when travelling westwards by train there is a fall of about 390 feet in a distance of about 24 miles between McLean and Regina. The hills to the north and south have about the same elevation as McLean. The plains to the south of Regina are slightly undulating for about 80 miles with a small fall to the north towards Regina.

As already mentioned, the author was instructed in 1911 to find out how best to augment the supply of water to Regina and in this connection about 1,000 square miles of territory were investigated, but of this area about 200 square miles were examined much more closely. Every spring and stream was located and its flow measured, the type and depth of every well was noted and the boundaries of watersheds were defined. The most promising area was the Boggy Creek watershed, which was found to have about 72 square miles, and the 1911 study was eventually concentrated upon it.

BOGGY CREEK WELLS

In the course of the investigations it was found that when the wells had been drilled through what the well drillers called "hardpan" the supply of water was usually abundant. It was also discovered, by

making a profile of the top water levels in the existing wells, that there was a fairly uniform grade westerly down the Boggy Creek valley. The City had previously acquired about 160 acres of land at the lower end of Boggy Creek watershed about 6½ miles N. E. of the City and the author recommended that three test wells be drilled there. The first well proved to be a gusher having a static head of over 12 feet above the ground surface. Two more wells were drilled, one of which had a static head of over 35 feet and the other about 30 feet. The work of well drilling was thereafter carried on without intermission until, by 1914, there were upwards of 40 wells, all overflowing. The City was put on full supply early in 1912. Well drilling operations ceased during the war, and at its termination more wells were necessary and well drilling was resumed, so that by now, to serve a population of about 60,000, 167 wells have been sunk on an area of about 2½ square miles, of which about 73 wells are flowing. There are two strata, one at an average of about 60 feet and the other at an average of about 180 feet.

The Boggy Creek wells are mostly 6-inch diameter, of which few are unproductive, 26 were test holes only. There are two 10-inch wells and two 12-inch Kelly Junior screen wells. The 10-inch wells have Cook screens. The life of steel casing in these wells is short, and in decaying admits debris which blocks the free flow of water.

The average total capacity of the Boggy Creek watershed is from 3 to 3½ million gallons per day. Some of the well water in Boggy Creek area is collected and delivered into the Tor Hill 5 million-gallon circular reinforced concrete reservoir, whence it flows by gravity go the City 5 million-gallon rectangular reinforced concrete reservoir and then is repumped to the City. These two reservoirs were built in 1914–15. The remainder of the Boggy Creek water supply passes into the pipe line of the water works which were built in 1904 by the late John Galt.

MALLORY SPRINGS

Reference was made in the 1911 Report to Mallory Springs. These are located 3 miles to the south of Boggy Creek works and 4½ miles east from the City. It was decided about 1927 to develop this area. Nineteen steel cased wells were drilled, of which 13 were test holes for purposes of exploration, and in 1928 two 18-inch Kelly wells with electric driven Pomona pumps were installed. There is a 12- to 18-inch woodstave pipe line connecting these wells with the City reservoir.

KELLY METHOD OF WELL SINKING

The Kelly method of well sinking is similar to that employed by other firms. Steel cylinders are made to sink to the underside of the water-bearing strata by removing the material from within. The cylinders are larger by several inches than the outside of the Kelly concrete screens. These screens are in sections about 12 inches long with thicknesses varying from $1\frac{1}{4}$ inches for 12-inch inside diameter, to 3 inches for 18-inch inside diameter.

There are narrow vertical slots on the outside of the screen sections which extend inwards into the concrete and downward to the bottom of each section. Each of the sections has four bosses underneath, which keep the screens slightly apart and are also used to line up the sections. The water passes through the slots to the small openings between the sections into the interior of the well. Four steel rods are inserted through the sections to keep them in line.

The bottom of each well is plugged with concrete and on it the screens are placed. As screened gravel is placed in the annular space between the concrete screens and the steel cylinder, the steel casing is raised and eventually removed. Plain concrete pipes are inserted through non-water-bearing stratas.

Mound Springs were dealt with in the 1911 Report, to which reference will be made further on.

FURTHER STUDY IN 1929–30

The introduction of new industries into the City caused the population to increase greatly, and consequently the margin between the consumption of water and the capacity of the works was becoming insufficient, with the result that the City Council in 1929 again requested the author to extend the investigations. This time W. A. Johnston, Chief of the Division of Pleistocene Geology and Water, of the Geological Survey, Ottawa, and Howard E. Simpson of North Dakota, geologist, and Nicholas S. Hill, Jr., New York, consulting engineer, collaborated on the investigations and reports.

The enquiry of 1929–30 covered a much larger field for it included every suitable source of water within a range of about 100 miles of Regina.

The district around Regina was explored, by test wells, for underground water. The results of those on the east side, apart from Mallory Springs, were disappointing. The district lying south and west of the City is not a favorable one for abundant underground

water supply. As described in this paper, Boggy Creek on the northeast has continued to supply water to the City for over twenty years: the remaining area is that of Mound Springs, about 14 miles north of the City, and certain smaller areas between, and it was recommended to the Council that this would be the next source to develop. Twelve wells were sunk near the Mound Springs, of which three were not satisfactory, leaving nine wells with individual initial flows of from 90,000 to 500,000 gallons per day with static heads varying from 8 to 24 feet. The depth to the lower limits of the water-bearing strata was from 54 to 155 feet. The reported thickness of the water-bearing strata was from 7 to 77 feet, averaging about 36 feet. The watershed to these springs and wells is estimated at 45 square miles, and the aggregate yield at about 2,000,000 gallons daily.

This water will be pumped from a central point to a new 10 million-gallon reservoir on a height of land about 4 miles north of the City, whence it will flow by gravity to the City reservoir and be repumped into the City.

The total estimated quantity of water available from Boggy Creek, Mallory Springs and Mound Springs, will be about 8,000,000 gallons daily.

PERCOLATION OF RAIN WATER

When considering the matter of the aggregate yield of the wells in this part of Saskatchewan it is necessary to bear in mind the conditions which influence the percolation of rain water to the underground strata.

In the case of early snowfalls, when the ground is relatively warm, most of the water will then percolate. When the ground becomes cold, however, melted snow freezes and percolation more or less ceases until the following springtime. There may be exceptions to these conditions. When the ground surface becomes frozen it may have contraction cracks which will admit water for a time, but, ordinarily, most of the snow water passes into streams, and where conserved in a few sloughs it is available only for local use at the end of the winter.

The consumption of water by vegetation and that lost by evaporation in the West is very considerable. For example, wheat on summer fallow during a growing season can make use of nearly 18 inches of rain compared with 10 inches when wheat is raised on stubble.

The quantity of water used per pound of grain will roughly be 1,000 pounds on fallow and about 1,450 pounds on stubble. In any dry season these figures will be more than twice as great. One important function of letting land stand fallow for a season is that it will conserve moisture. Wheat raised on fallow, therefore, has the advantage of drawing upon the moisture of part of two seasons. Moreover some of the rain falling on fallow land will percolate and help to replenish the underground strata.

The average rainfall of 39 years was 12.62 inches (excluding snow), compared with 5.60 inches in 1929, 5.75 inches in 1894, 7.93 inches average of 1891–94 and 8.66 inches in 1890–94. Inasmuch as the crops, and nature generally, make a great demand on the rainfall during the growing seasons of dry years, when, fortunately, most of it occurs, the replenishment of the underground sources is retarded until the end of this season. This means from the end of April to the end of August.

During seasons of limited rainfall the time when rain will freely percolate into the ground is therefore after the ice has disappeared and nature makes it heavy demand and also between harvest time and when the ground is again icebound.

Transpiration, with its allied problems of evaporation, is a matter of importance where there is less humidity than that experienced in Ontario.

Summarizing the above statements, the average (17 inches) of 30 years' records shows that the proportion of snow and rain falling is 24 percent during winter, 63 percent during the growing season, and 13 percent during the period of percolation. In dry years, however, the proportions are, winter about 35 percent, growing season about 55, and in the percolation period about 10 percent.

TASTE AND ODOR REMOVAL[1]

By L. F. Warrick[2] and O. J. Muegge[3]

Tastes and odors in public water supplies are the source of much trouble for waterworks officials, both from the points of view of answering complaints of irate water consumers and determining effective methods to eliminate the difficulties. Due to the fact, furthermore, that the consumers will frequently turn to private well or spring supplies, often of questionable sanitary quality, rather than use an ill-smelling or tasting municipal supply, a very definite menace to public health and welfare is occasioned in such cases. Such conditions have recently existed in some Wisconsin municipalities. The purpose of this paper is to describe briefly the major causes or sources of tastes and odors in water supplies and to review various methods which are at present being used to overcome these objectionable characteristics.

The senses of taste and smell are intimately associated but nevertheless distinct. Sugar has a definite taste but no odor, while vanilla has a strong odor but no taste. Some so-called tastes, however are really odors which are due to gases or vapors that are impressed on the olfactory nerves either through the nose or through the posterior nares as the substance is "tasted." Because of the close relationship between smell and taste, and since most offensive tastes observed in water supplies are due to organic matter in solution or suspension, or to minute organisms, which produce both odors and tastes, the term "odor" is used herein to describe attributes of waters that may affect both senses.

In general, water obtained from ground sources and used immediately is odorless. Where allowed to remain in storage under certain conditions or to stagnate in dead ends of distribution systems, odor difficulties are occasionally encountered with ground water supplies. Some deep well waters have sulphurous odor, while wells receiving

[1] Presented before the Wisconsin Section meeting, August 21, 1930.

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pollution from surface drainage, particularly from swampy regions, may produce waters of a moldy or otherwise disagreeable odor.

Surface supplies are most likely to develop objectionable odor characteristics. These odors have been grouped by Whipple, Fair and Whipple (1), according to source, as follows:

1. Odors, caused by organic matter other than living organisms.
2. Odors caused by living organisms.
3. Odors caused by chlorine or chlorine compounds and by the action of chlorine upon any of the preceding odor-producing agencies.

Disinfection of public water supplies by means of chlorine has occasionally given rise to difficulty due to odors resulting from one or more of the following causes:

1. "Free" or excess chlorine.
2. Substances formed by the combination of chlorine with organic matter of vegetable or animal origin.
3. Products formed by the combination of chlorine with phenoloid or comparable substances.
4. Destruction of organisms with the liberation of aromatic substances which in some instances unite with chlorine.

Tastes of free or excess chlorine are due to the application of more chlorine than is necessary to satisfy the demand of the organic matter. In some waters such as well or filtered water, a small dosage will cause a taste, whereas in waters high in organic matter a much higher rate of application can be and is utilized. With rather frequent control such as is commonly practiced today, and with the maintenance of free chlorine between 0.1 and 0.2 p.p.m. complaints due to this cause are now relatively infrequent.

The addition or combination of chlorine with organic matter, especially with large amounts of decaying vegetation or animal matter, will cause objectionable tastes varying from "woody" to "medicinal" in character. Combination of chlorine with phenols, cresols, and other coal tar derivatives, which find their way into water chiefly by the discharge of wastes from coke by-products plants, gas plants, and similar industries, will cause what is frequently termed as "iodoform" taste, perhaps the most objectionable of all tastes in water supplies. Extremely small amounts of phenols such as one in one billion, will produce tastes in certain waters.

Chlorine, when used in sufficient quantity, will destroy algae as well as bacteria, liberating the essential or aromatic odor-producing

oils. These substances, then, in some cases, combine with the chlorine to produce objectionable and intensified odors, often bringing out odors that are not noticeable in the raw water. In fact, it has been reported that Synura is noticeable in chlorinated water before its presence can be discerned under the microscope.

METHODS OF CONTROL

The methods of controlling and eliminating tastes and odors necessarily depend upon the causes of such conditions, there being no common panacea. In fact, with different water supplies, different treatment is often required to accomplish the elimination of similar taste and odor producing substances.

In ground water supplies the presence of iron and manganese, accompanied frequently by sulphurous odors, is the cause of many complaints due to subsequent deposition of iron and stimulation of the growth of crenothrix. The problem of removal of these inorganic salts is mainly that of oxidation with liberation of carbon dioxide and of hydrogen sulfide, when present. In waters where the amount of iron is low and little or no manganese or organic matter is present, sufficient oxidation may often be secured by pumping with air-lift or by open discharge into a reservoir. In other supplies, however, the problem is not as readily solved and more elaborate treatment consisting primarily of aeration, with or without contact material, sedimentation and filtration, must be installed. Care should be taken not to over-aerate since in some waters complete aeration will be distinctly harmful. Some time coagulation with chemicals is used to advantage.

The installation of iron removal plants will in due time result in the elimination of growths of iron bacteria, crenothrix. Prior to the construction of such plants control or destruction of crenothrix growths often can be obtained by the use of chlorine. Since 0.54 p.p.m. (2) is necessary to destroy these organisms, an amount which would impart a taste to most waters, it is desirable that the section of mains to be treated be isolated and then thoroughly flushed before again being placed in service.

In surface water supplies where algae are the odor producing agencies much can be done to control the growths by the application of copper sulfate to the lake, storage reservoir, or stream from which the supply is secured. The method of application is relatively simple and consists of dragging bags of crystals through the water. The

boats should travel in a zig-zag path or at definite intervals so that the application will be uniform for all areas. Dosage should be apportioned according to depth by varying the speed of the boat, and care should be exercised to prevent too great a concentration of copper in order to avoid poisoning of fish. In shallow water more effective treatment can usually be obtained by spraying the solution over the surface.

Where the water to be treated passes by a certain point, such as in a flume or open channel, application of copper sulfate by means of dryfeed equipment merits serious consideration since it will permit more uniform application.

Use of copper sulphate in control of algae growths should not be hap-hazard. If applied in too small amounts the algae will not be destroyed, and if too much is used there is danger of killing fish. The proper amount should be predetermined which will depend upon the organism to be destroyed, the amount of organic matter and carbonic acid, the hardness, temperature, and quantity of water, and other controlling factors. Preferably the application of copper sulfate should be under the supervision of a competent chemist or biologist.

In some instances, algae as well as taste and odors due to presence of organic matter can be controlled by development work on the lakes, reservoirs, and streams, such as removing vegetation, muck, and other material from the sides and bottom and the elimination of swampy areas by drainage.

Aeration is of great success in removing tastes and odors. The benefits consist in the removal of gases, such as carbon dioxide, and volatile organic matter which give the water the unpleasant characteristics. The aromatic substances, incident to the growth and decay of algae are appreciably reduced by aeration, the extent of such removal being dependent upon the type of organisms. Violent aeration, as by spray nozzles, may result in destruction of the more fragile organisms. Incidentally the addition of dissolved oxygen is also of value in water low in oxygen since it tends to prohibit anaerobic conditions in the sedimentation basins, particularly in those of large capacity.

The effect of aeration in removal of tastes and odors due to presence of phenols, cresols, and other comparable matter is less marked since these substances, apparently, are less volatile and thus not so easily swept out.

Aeration just subsequent to the addition of alum tends to hasten floc formation and reduce the amount of coagulant necessary. The carbon dioxide freed in the reaction is also liberated. Following coagulation or filtration, aeration is frequently of benefit in the production of a less corrosive water.

Pre-chlorination as practiced quite generally today has been of material aid in the purification of water in that chlorine has tended to combine with the organic matter and destroy the microörganisms, resulting in better coagulation and increased filter runs. By the oxidation of the organic matter certain taste and odor producing substances have undoubtedly been eliminated directly, and others by the increased effectiveness of the purification processes.

As previously outlined, however, chlorine in some cases has combined with the organic matter to form intensified odors, or has acted as an algicide liberating the aromatic substances. Fortunately it has been determined that a large excess dose of chlorine will tend to destroy such odors either by oxidizing the substances or by formation of odorless compounds. This method is known as super-chlorination and has been used with great success on the New York water supply and at other places.

Such super-chlorination has also proved of value in the elimination of chloro-phenol tastes, the most excellent example being that of Toronto. Here the water is treated with 6 to 10 pounds of chlorine per million gallons and de-chlorination obtained by the use of sulphur dioxide. Pertinent conclusions based on the preliminary work at Toronto are (3):

"Definite time contact periods are necessary for varying doses of taste-producing substances to effect their destruction.

"The contact period can be shortened by greatly increasing the chlorine dosage.

"A definite excess of sulphur dioxide is necessary to remove all traces of residual chlorine."

Potassium permanganate has also been used as a preventive of "iodoform" odors, having proven of great merit at Rochester and Buffalo, N. Y. The dose of permanganate necessarily varies with the oxidizability of the water. Like chlorine in excess permanganate is a taste remover and preventer. Its main objection is the likelihood of causing stains or adding color to the water. Under certain methods of application, such as permanganate treatment before filtration followed by chlorination, tastes may be produced due to

combination of chlorine with organic compounds leached out of the filter after the permanganate has been used up. At Charleston, W. Va., the permanganate treatment which was tried during 1929, was replaced with ammonia treatment because of better elimination of odor.

The treatment of water with chloramines, or by ammonia and chlorine, is rapidly gaining favor throughout the nation as a means of preventing chloro-phenol tastes. Cleveland has obtained excellent results through the use of this treatment as has Springfield, Illinois, Philadelphia and Lancaster, Pennsylvania, and Greenville, Tenn., the latter place being the first to institute such treatment in the United States. The sterilizing action of chloramines is considerably slower than that of chlorine and therefore, more time is required between the time of application and discharge of water into the distribution system. The advantages of the process as summarized by J. W. Ellms, Cleveland, and presented in a paper before the 50th Annual Convention of the American Water Works Association, are as follows (4):

"1. No chlor-phenolic tastes have been noted since beginning the application of the ammonia prior to chlorination.

"2. Chlorinous tastes from residual chlorine have been eliminated.

"3. The taste of the water is more acceptable than ever before, and no complaints from consumers have been received.

"4. The bacterial efficiency of the process is as high, if not higher than when chlorine only is used.

"5. The prolonged inhibitory effect on bacterial growths is of great value in maintaining a water in its highest state of purity throughout an extensive distribution system.

"6. The cost of the equipment for applying ammonia is merely nominal, and may be readily adapted to any existing water plant."

Recent experimental work has indicated that activated carbon may be of value in removing taste and odors from water and for dechlorination subsequent to super-chlorination. No practical or complete purification plants using activated carbon have been installed, although experimental work by Baylis (5), Norcom and Dodd (6), Ernst Watzl (7) and Sartorius and Ottemeyer (8), have indicated that use of this material has possibilities in water purification.

In conclusion, it is to be emphasized that much is still to be learned about control of taste and odors in water by the various methods reviewed. None of the methods outlined should be arbitrarily adopted at any water purification plant until thorough consideration and

tests have indicated that satisfactory results will be obtained. Each superintendent or chemist of a water purification plant can increase our knowledge by making accurate observations of the processes employed and by doing experimental work, toward the elimination of tastes and odors. Such experimental work, however, to be of most value necessitates that an accurate record of observations is kept. A complete report on a failure to secure results is of as much value as a report on a successful means of control.

REFERENCES

(1) WHIPPLE, FAIR AND WHIPPLE: "The Microscopy of Drinking Water," 4th ed.; John Wiley & Sons, N. Y., 1927, page 50.

(2) Ditto, page 403.

(3) HOWARD AND THOMPSON: "Super-Chlorination of Toronto Water," Canadian Engineer, Oct. 19, 1926.

(4) ELLMS, J. W.: "Preammoniation of Filtered Water," Waterworks and Sewerage, Vol. 77, No. 8, August, 1930.

(5) BAYLIS, JOHN R.: "The Activated Carbons and Their Use in Removing Objectionable Tastes and Odors from Water," Jour. A. W. W. A., Vol. 21, No. 6, June, 1929.

(6) NORCOM AND DODD: "Taste and Odor Removed by Activated Carbon," Waterworks and Sewerage, Vol. 77, No. 8.

(7) WATZL, ERNST: "Superchlorination and Subsequent Dechlorination over Carbon for Municipal Water Supply," Presented before Amer. Chem. Soc., Sept. 13, 1928.

(8) SARTORIUS AND OTTEMEYER: "The Removal of Disturbing Substances in Drinking Water by Activated and Unactivated Carbon;" The Chlorine Institute, Inc., Sept., 1929.

THE WATERTOWN WATER SYSTEM[1]

By H. J. Haley[2]

As early as 1844, the trustees of the village of Watertown were desirous of obtaining a water supply. They obtained the services of Mr. Dewey, a civil engineer, who made surveys and examinations of two schemes of development. The first plan was to obtain a supply from Cold Springs, pump to a reservoir and distribute from there to the village. The second plan was to use Black River for a supply and elevate it to a storage, distributing it the same as in the first plan. No action was taken at that time, however, and it was not until March 22, 1853 that an act to supply the village with pure and wholesome water was passed. This act provided for a water board and the first commissioners appointed were Loveland Paddock, George C. Sherman, Isaac H. Fisk, William A. Angel, and Howell Cooper. At the first meeting March 26, 1853, Loveland Paddock was chosen president and George C. Sherman secretary. Naturally, the first problem before the board was to determine a plan for a water supply. Therefore, the advice of William A. Perkins, a competent engineer employed by the state, was obtained to make surveys and investigations. His report gave several plans for a supply and advised the use of cast iron rather than wrought iron cement-coated pipe.

The water board had previously obtained data on the so-called cement pipe from a manufacturer of this product. They were not convinced by the recommendations of their engineer, so an inspection trip was made to New York and Brooklyn where examinations and tests of this material were made. A favorable report was made to the water commissioners and it was decided to adopt the use of cement pipe with a five-year guarantee.

The use of steam or water power gave the board another problem. Therefore a committee was sent to Canada to make studies of their waterworks and pumping stations. Two plans for a water system

[1] Presented before the New York Section meeting, October 9, 1930.

[2] Superintendent, Water Department, Watertown, N. Y.

were debated by the commissioners. The most favorable one was to use Black River for a source of supply, pump to a storage reservoir at an elevation where it could be distributed by gravity to all parts of the village.

In 1853, a reservoir site containing twenty acres of land was deeded to the village by John C. Sterling, an executor of his father's estate, provided that an outlay of $250.00 be spent in constructing fences and beautifying the surroundings. An additional 6.5 acres was later purchased from Mr. Sterling after a survey showed that the deed contained this extra acreage.

The same year contracts were let for a pumping station with equipment, rising mains, a distribution system and also a reservoir to be constructed on the site deeded to the village. The pumping station was erected on Black River near Factory Square and was equipped with one horizontal double-plunger type pump, driven by water power. A reservoir 150 feet by 250 feet with a depth of 12-feet was built where our storage is now located. This was excavated to solid rock and the side walls made of puddled clay. A loose stone wall divided the reservoir, serving as a filter. The water entered the section farthest from the outlet, passed through the stone wall and to the outlet pipe. An 8-inch cement main was installed from the pumping station through High, William and Franklin Streets to the reservoir and a down-main from the reservoir through Franklin Street to Public Square. Some 6 miles of distribution mains were installed at that time varying from 1 to 12 inches in size. The cost of this installation was as follows:

Reservoirs and pumphouse	$7,500.00
Machinery, waterwheel and pump	2,500.00
Rising and distribution mains with hydrants, valves, etc.	35,000.00
Total	$45,000.00

According to the act of incorporation the commissioners were authorized to issue corporation bonds for $50,000 and the contracts were therefore well within that limit.

During November, 1853, the pumping station was placed in service and operated very satisfactorily, easily elevating the water to the reservoir. However, much trouble was experienced with constant leakage from the reservoir and mains. This loss in the mains occurred not only at the sleeves, but was due to defective linings and insufficient rivets. The contractors were called upon to make many

repairs at their own expense and the final payment was not made until the work was completed to the satisfaction of the water board.

The system was then dependent upon one pumping station which obtained its supply from a source that encountered anchor ice in winter and low water in summer. It was evident that this unit, if taken out of service for repairs or unusual river conditions, would leave the village without an adequate supply of water and therefore in 1860, a second pumping station was erected on Beebee's Island. The pumping equipment first installed there failed to operate to capacity and was removed at the expense of the designer. The contract for two double acting piston pumps, water driven, was then given to the Bagley and Sewall Company of this city.

This station was connected with the 8-inch rising main from the upper station by a 10-inch line passing through Mill Street across Public Square to Franklin Street and south on Franklin Street to William where it joined the 8-inch line from the upper station and the 10-inch line to the reservoir. The two pumping stations, with several changes in equipment were in operation until our present station was placed in service.

As the system enlarged, it was necessary to obtain more and better storage and in 1872 a second reservoir was constructed just east of the first unit. This was excavated in rock, 240 feet by 130 feet with a depth of approximately 20 feet and the side walls built of stone laid in lime mortar. The smaller reservoir was taken out of service at the completion of the new storage. This new reservoir also required many repairs to check the leakage and it was not until 1878 that the contractors were given their final payment of $3,000 for the satisfactory completion of their contract.

In 1909 and 1910, the small abandoned storage was deepened and side walls constructed of concrete giving it a capacity of 3,000,000 gallons, and the larger unit was also lined with concrete and the walls raised to provide a storage of 5,000,000 gallons.

The use of cement pipe continued until 1874 when the department installed 4-inch cast iron mains in Arsenal and Orchard Streets. The section comprising the south side of the river was well provided with a distribution system that was ample for the needs at that time, although the records show that the north side had no mains.

The system was expanding and the cement pumping mains were causing trouble with breaks; therefore, in 1878 it became necessary to install 12-inch cast iron discharge mains from each pumping station

to the corner of High and William Streets and a 16-inch line from here through William Street to Franklin and south on Franklin to the reservoirs.

The north side of the river was connected with the system in 1887 when an 8-inch main was laid across the Court Street bridge. Later, this main was replaced by a 12-inch. This section of the city expanded rapidly and it was necessary to install additional mains to supply the demand. At present there are three 8- one 12- and one 16-inch mains supplying this section.

Our present pumping station was erected in 1882 and an addition built in 1897. This was originally equipped with two R. D. Wood horizontal duplex pumps driven by 150 H. P. water wheels. Later two Harmon, 3,000,000 gallon, three stage centrifugal pump and in 1908 a 12-inch Worthington centrifugal, 5,00,000 gallon capacity, were added to the station. All of these units were operated by 250 H. P. water wheels. Later, the Harmon and Wood pumps were taken out of service and a 12-inch Kingsford, electric driven and a 12-inch Cameron, electric or beltdriven, each of 5,000,000 gallon capacity, were added. This pumping station at present is operated by water power approximately five months of the year and uses electric power from the municipal power plant the remaining seven months, with usually one pump supplying service.

Our pumping mains are of 16- or 24-inch in size. The 16-inch that takes the discharge from the Kingsford pump was installed from our pumping station to the reservoir in 1880. The 24-inch was built from 1897 to 1899 from the station to Pearl Avenue and in 1905, it was extended to connect with Public Square and west in Pearl Avenue to State Street. During 1910, this trunk main was extended from State Street to connect with the 16-inch trunk main near our reservoirs.

There have always been citizens who advocated a different water supply than that of Black River. At different times the question of a new supply has been brought before the Board of Water Commissioners. This question arose in 1902 and the city engineer was directed to obtain data and costs for a new supply. Several different sources were found practical and Crystal Lake in the Adirondacks and Lake Ontario near Sackets Harbor were two of the supplies recommended. The supply lines varied from 33 to 12 miles in length and the costs from $1,410,000 to $656,000 with an additional $70,000 for a filtration plant. This large cost prohibited the con-

struction of a new supply, so in 1903 Mr. Allen Hazen was authorized to prepare plans and specifications for a filtration plant, containing 8 filters, capacity of 6 m.g.d., and at a cost not to exceed $100,000. Contracts were let that year and the plant was operating in September, 1904.

Again during 1915, Hazen, Whipple, and Fuller made studies and comparative estimates for a new supply and also for enlarging the system then in use. In their report to the Board of Water Commissioners, they recommended the Sandy Creek supply as being the most economical of any of the new supplies studied. The estimated cost was $790,000 and the annual operating expense would be $51,000. The enlargement of the Black River supply was estimated at $100,000 with a yearly expense of $40,000. It was, therefore, decided in 1917 to enlarge our filter plant by the addition of four filters of 820,000 gallons each.

PRESENT SUPPLY SYSTEM

Our present supply is obtained from Black River where two concrete dams built across the north channel of the river form a coagulating basin with a storage of 60,000,000 gallons. This water is pumped through a 30-inch supply line to an areator by a Lawrence single stage centrifugal pump located in our pumping station. The water then flows by gravity to a 1,000,000 gallon basin and then to the filters. The water, after leaving the filters, is chlorinated and flows to a 750,000 gallon clear well, and continues to the suction of our three pumps.

In 1920 our records showed that there were a total of 55.0 percent of 4-inch mains in the distribution system. The fire underwriters report of 1926 gave 49.9 percent and at the present time there is a total of 47.7 percent.

A summary of the main construction, including hydrants, from January 1, 1920 to July 1, 1930, is given in table 1.

From an examination of table 1 it will be noted that the department installed only 552 feet of 4-inch mains in a total of 32,520 feet or 1.7 percent. All mains are located 10 feet from center line of the street and are usually laid with a 4- to 5-foot cover, depending upon location and conditions. This location insures no interference with future curbing construction. Sufficient gate valves have been installed so that a small section can be isolated in case of a breakdown in the service. The fire protection in the districts covered by this

TABLE 1

Summary of main and hydrant construction, Watertown, N. Y., January 1, 1920 to October 1, 1930

YEAR	16-INCH		12-INCH		10-INCH		8-INCH		6-INCH		4-INCH	
	Feet	Cost	Feet	Cost	Feet	Cost	Feet	Cost	Feet	Cost	Feet	Cost
1920							1,050	$4,252.50	525	$1,279.66		
1921			877	$5,870.78					723	1,825.03		
1922									523	1,222.13		
1923			60	799.98					1,943	6,566.77		
1924			128	812.80			4,187	14,764.01	3,477	8,645.15	246	$735.55
1925							1,292	5,804.00	2,209	6,754.81		
1926	913	$7,646.64	7	71.26			50	643.27	254	888.78		
1927					3,165	$15,726.43	1,283	6,249.64	726	3,026.74	306	24.87
1928							924	2,014.57	764	4,792.49		
1929	198	2,108.28	1,671	8,402.02			2,107	12,681.03	1,476	2,905.76		
1930									424	1,220.04		
	1,111	9,754.92	2,743	15,956.84	3,165	15,726.43	11,893	46,409.02	13,056	39,127.36	552	760.42
Average cost per foot		8.70		5.81		4.97		3.90		3.00		1.38

Total mains including hydrants, 32,520 feet	$127,734.99	Average cost per foot	$3.93
Extra hydrants installed (79)	15,338.58	Average cost per hydrant	$194.16
Total cost	$143,073.57		

main installation has been greatly improved as only 6-inch steamer type hydrants are used with a 6-inch gated connection to the main.

Class B, cast iron tarred pipe was universally installed to July, 1927. At that time, the department decided to use centrifugal cement-lined pipe so as to obtain a greater carrying capacity due to less corrosion. This type weighs less per foot, costs less and being made in 16- and 18-foot lengths, can be installed cheaper.

PITOMETER SURVEY

In 1928 the Pitometer Company made a study of our distribution system to determine what immediate improvements were necessary to bring the system to an efficient state and also to map out a program to maintain this efficiency to 1955. This study plans improvements to the distribution grid, especially to give adequate fire protection to all parts of the city by adding subfeeder mains, replacing 4-inch with larger mains, installing additional 6-inch mains and replacing of 4-inch hydrants with new ones connected to the 24-inch main. The department began construction according to this plan in 1929 and has laid to date 11,000 feet varying in size from 6- to 12-inch. Since July, 1930, we have installed 5,000 feet of 6- and 8-inch in residential sections, replacing 4-inch mains. Previous to January 1, 1920, only 891 meters had been installed which was 15.5 percent of the service. During 1920, 1,284 were set and this program continued to July 1928, when the system became 100 percent metered. It was necessary in 1928 to install 1,719 $\frac{5}{8}$-inch meters for flat rate consumers to complete this installation and the average cost per unit was $11.50.

All meters are furnished and installed free to the consumer. These are also maintained by the department and the only charge is for damage caused by freezing or hot water. Formerly, all meters larger than $1\frac{1}{2}$-inch were owned by the consumer. These have been purchased at original cost less a 5 percent depreciation per year for their use, and at the present time, the department is the owner of all meters totaling 6,800.

SERVICES

Prior to 1925, wrought iron and some cement-lined pipe were used for services. The department is renewing the older wrought iron services at the rate of 200 a year. The cement-lined pipe has been in use six to seven years and I have no record of any of these being replaced. The first copper service was installed in April, 1925 and the department has standardized on this material for all construction

from the main to the property line. At the present time, the system has 900 ¾- and 300 1-inch copper services and I know of no case where repairs were necessary on any of the work. We renew all services to the property line at no cost to the consumer and make a charge of $2.00 for a new ¾-inch service and $7.00 for a 1-inch. These rates were established by an ordinance adopted September, 1927 which Mr. Ackerman, our former City Manager, was instrumental in formulating.

It was necessary to divide our city into three equal districts for domestic consumers after we were 100 percent metered. This insured an equal reading and billing program each month and has proven very satisfactory to the department. Our average number of domestic consumers on full time is 6,340, within additional 488 who use water during the summer months for truck gardens, etc., and 117 industrial or commercial users.

CONSUMPTION AND RATES

Our daily average per capita for the fiscal year 1929 was 137 gallons and our daily average consumption was 4,400,000 gallons. A graphical history of the water consumption and the meter installation from 1913 to the present time is shown in figure 1. The decrease in the average daily per capita shows conclusively the results that can be obtained by the metering of flat rate consumers. It was the usual practice when the city was only partially metered to notify consumers that water must be conserved. During the continued drought of the past summer when many cities experienced a shortage this department had no difficulty in delivering unlimited quantities to all consumers.

Our water rates were also revised according to the ordinance adopted September 7, 1927. This provided for a graduated rate varying from 9 to 5 cents per 100 cubic feet with a service charge depending upon the size of the meter. A fire service charge was also established and was based on the size of the fire line supplying the property. These rates are given in table 2.

This ordinance also provides a hydrant rental charge which is based on the inch-feet of mains installed of 6-inch in diameter or larger and $20.00 for each standard hydrant having a steamer and two hose nozzles with a minimum gated branch of 6-inch or larger. This charge is optional with the council, depending upon the needs of the department.

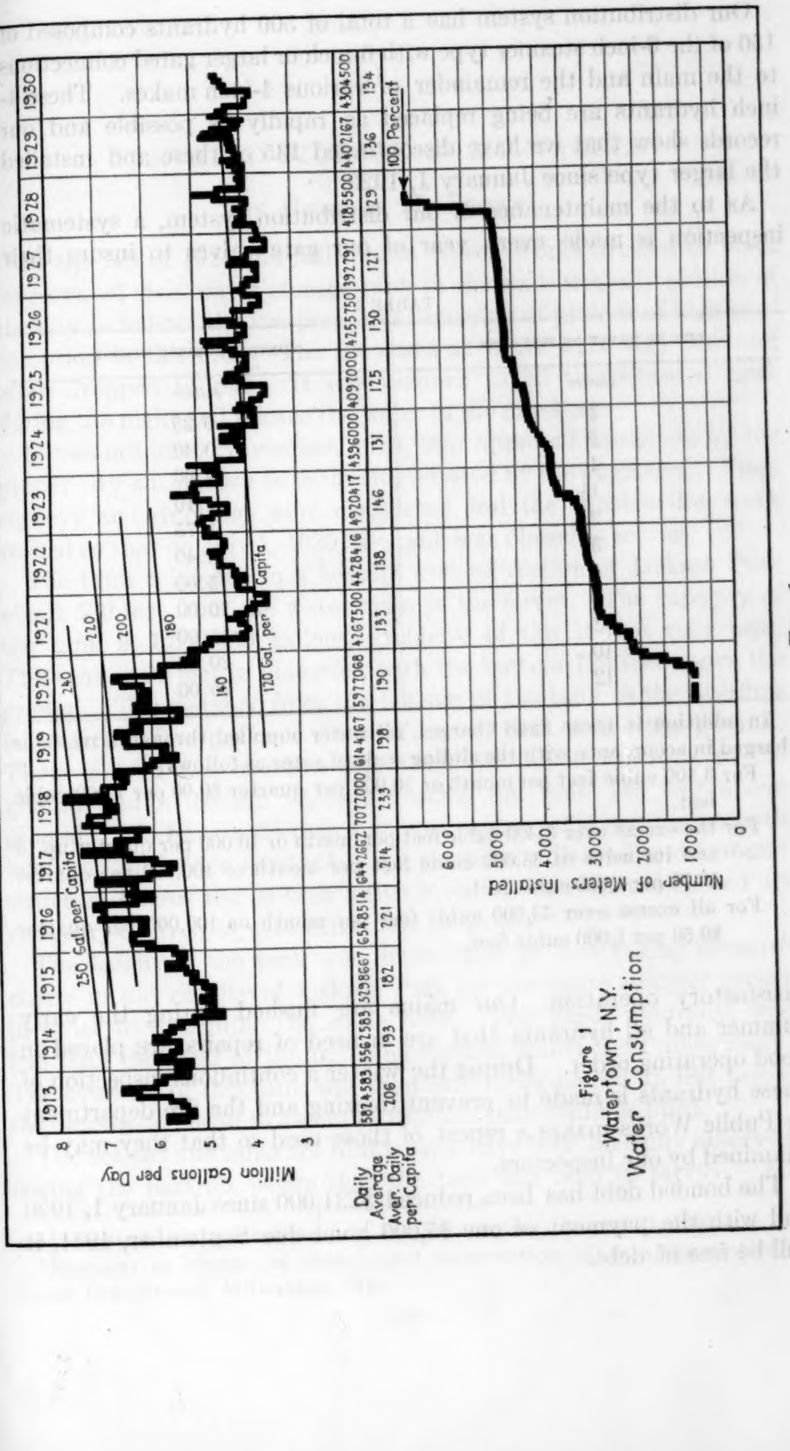
Figure 1
Watertown N.Y.
Water Consumption
Million Gallons per Day
Number of Meters Installed
Daily Average
Aver. Daily per Capita
1913
1914
1915
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928
1929
1930
250 Gal. per Capita
240
220
200
180
140
120 Gal. per Capita
100 Percent

FIG. 1

Our distribution system has a total of 500 hydrants composed of 150 of the 6-inch steamer type with 6-inch or larger gated connections to the main and the remainder of various 4-inch makes. These 4-inch hydrants are being replaced as rapidly as possible and our records show that we have discontinued 135 of these and installed the larger type since January 1, 1920.

As to the maintenance of our distribution system, a systematic inspection is made every year of our gate valves to insure their

TABLE 2

SIZE OF METER OR FIRE LINE	MONTHLY SERVICE CHARGE
inches	*dollars*
5/8	0.25
3/4	0.40
1	0.60
1½	1.10
2	1.75
3	3.40
4	5.00
6	10.00
8	15.00
10	20.00
12	25.00

In addition to these fixed charges, all water supplied through a meter is charged in accordance with the sliding scale of rates as follows:

For 3,300 cubic feet per month or 10,000 per quarter $0.90 per 1,000 cubic feet.

For the excess over 3,300 cubic feet per month or 10,000 per quarter up to and inclusive of 33,000 cubic feet per month or 100,000 per quarter $0.70 per 1,000 cubic feet.

For all excess over 33,000 cubic feet per month or 100,000 per quarter $0.50 per 1,000 cubic feet.

satisfactory operation. Our mains are flushed during the early summer and all hydrants that are in need of repairs are placed in good operating order. During the winter a continuous inspection of these hydrants is made to prevent freezing and the fire department or Public Works makes a report of those used so that they may be examined by our inspectors.

The bonded debt has been reduced $231,000 since January 1, 1920 and with the payment of one $5,000 bond due September, 1931, it will be free of debt.

ELEVATED STORAGE IN MILWAUKEE[1]

By Herbert H. Brown[2]

In the fall of 1928 the Milwaukee Water Works decided to erect an elevated steel water storage tank in the southwesterly section of the city to bolster the low pressures occurring at periods of high consumption in this area. The pressures at times were very low and often dropped to zero. It was planned to fill this elevated tank during the night and release the water in the day-time.

It was not until November, 1929, that approval was given by the proper city authorities as to the site selected by the engineers. Final surveys and drawings were completed and the construction work rushed so that on July 1, 1930, the tank was placed in service.

The tank is located in a heavily wooded section of Jackson Park about 530 feet from the water main in the street. The capacity of the tank is 1,500,000 gallons, exclusive of the 10-foot riser pipe. The tank is 79 feet in diameter, with the bottom 120 feet above the ground. The distance from the bottom of the tank to the overflow is 50 feet. The peak of the roof is 187 feet above the ground. There is a 12-inch overflow pipe from the top of the tank to the ground and a 36-inch balcony around the tank 143 feet above ground. We have a 24-inch cast iron water main serving as both inlet and outlet for the tank. An electrically lighted underground structure houses the 24-inch altitude valve, blow-off valves and all necessary controlling gate valves and by-passes.

The height of the tank was determined by first taking pressure charts in the vicinity of Jackson Park for the entire summer period in order to determine the static head. This head, naturally, was less than the head at the pumping station, which is 10 miles away. The overflow of this tank was then arbitrarily placed 15 feet below the determined head to assure us that the tank could be filled.

The actions and influence of this tank have been carefully observed during the past six weeks that the tank has been in service. All

[1] Presented before the Wisconsin Section meeting, August 21, 1930.

[2] Engineer in charge of design and construction of pumping stations, Water Department, Milwaukee, Wis.

water works equipment received an unusually severe test during the month of July, when we had one of the hottest and driest periods in 40 years. The Jackson Park structure was the first elevated tank that the City of Milwaukee ever built. We had no experience to back us. All our work was new and we had to find out how closely the service performed by the tank came to our estimates and anticipated needs under the local conditions.

Bearing the above facts in mind, I should like to report how our tank has functioned to date. One of the problems that could not be decided before the contracts were let for the tank was as to whether the altitude valve should be constructed to permit the tank to "float on the line" or whether a pressure differential should be incorporated to retain all the water in the tank until the street pressure fell a predetermined amount. If the later procedure was incorporated, what should this differential be, 5, 10, or 15 pounds? It should not be too much to prevent enough circulation of water in the tank and cause stagnation.

Soon after the tank was placed in service, we found that on a hot day the morning consumption was so great that it drained a great deal of water out of the tank. The result was that when our peak consumption came in the early afternoon, we had only one-half tank in reserve and this water was not enough to satisfy the demand. So we had an empty tank when we needed most water. This demonstrated clearly that we could not permit the tank to "float on the line" during the hot summer months.

Pressure recording charts had been placed on the distribution system at various points in the area affected by the operation of the tank. By daily and careful observation of these pressures we soon concluded that a 5, 10 or even 15 pound differential in our altitude valve would not satisfy all conditions. By continued observation of these charts we found that differentials of 20, 25 and even 30 pounds would not operate the tank in the manner we desired.

It was concluded therefore that the tank should not operate on a pressure differential, but on a time basis. We experimented further by manually closing the altitude valve at 5 a.m. after the tank was filled, allowing the water to remain in the tank all day and then manually opening the altitude valve at 5 p.m. The automatic operation of the valve was allowed to remain in service from 5 p.m. to 5 a.m. in order that the tank would not over-flow when filled during the night. This method of operation has proved more

satisfactory and is evidently the proper one to use. We are now installing a solenoid operated valve connected to an electrically wound time switch, to eliminate the necessity of a man traveling to the tank site twice each day and turning the altitude valve by hand.

We anticipate that this time operation of the tank will be necessary only during the hot summer months and that during the spring and fall of the year the tank can simply "float on the line."

We anticipate, also, that conditions in our distribution system, which are continuously changing from year to year, will have a marked influence on the operation of this tank and only careful observation will guide us in determining the most effective manner of operation.

There is one more factor in our operation which it is important to bring to your attention. I refer to a surge or water hammer created in the water mains by opening or closing the altitude valve too quickly. We originally set the altitude valve to open slower than it closed so there would not be a sudden rush of water at high head into the distribution system. This setting opened the valve in 30 seconds. As soon as we started to operate, however, we noted a 40-pound surge when the altitude valve was closed. This surge was carried back 10 miles to the pumping station, where a 6-pound rise was recorded on the charts. The surge, of course, was only momentary and was recorded on all the charts by the pen-arm rising vertically and immediately dropping to its original position. An adjustment has been placed on the altitude valve and we now have it set to open or close in 2½ minutes which causes a surge of only from 6 to 14 pounds at the tank.

Our maximum daily consumption increased 6.5 percent this summer and our maximum hourly consumption 8.8 percent. In spite of these increases we did not receive a single complaint from inside the city about low pressures. We are proud of this record and feel that the installation and operation of the elevated tank has greatly assisted in making this record possible.

THE WATER SUPPLIES OF LE ROY AND TICONDEROGA, NEW YORK[1]

By James P. Wells[2]

Le Roy is situated about 45 miles east of Buffalo in the center of western New York's agricultural country. Historic Ticonderoga is at the extreme eastern part of the State at the edge of the Adirondack Mountains near Lake Champlain and at the north end of Lake George.

In years gone by Le Roy's problem was where to obtain an adequate supply of water. At Ticonderoga the question that presented itself was which source to choose from several supplies.

LE ROY SUPPLY

Previous to 1916 Le Roy obtained its water from shallow wells. The supply was inadequate and the water was hard. After investigating the possibilities of a gravity supply, the writer recommended the construction of a storage dam on a stream absolutely dry for several months of the year and located about 6 miles south of the village. The work was carried out by the construction of an earthen dam 32 feet high creating a reservoir which impounds 145,000,000 gallons of water. A rapid sand filter plant was built directly in front of the dam and a 14-inch pipe line leads to the village. The earthen dam has a length of about 500 feet. The slopes are 1 on 3 on the upstream side and 1 on 2 on the downstream side of the dam. A corewall 2 feet wide on top and 5 feet thick at the bottom extends to a height 3 feet above high water and 17 feet below the floor of the valley to impervious underlying shale. The spillway at one side is 60 feet long and 5 feet deep. Just prior to the completion of this dam the spillway had to take the tremendous flood from $1\frac{1}{2}$ square miles of catchment area of 3 feet 9 inches over the crest, which taking into consideration the fact that the reservoir was not entirely full at the time, I estimate at 3,000 cubic feet per second. It is interesting

[1]Presented before the New York Section meeting, September 22, 1931.
[2]Consulting Engineer, Rochester, N. Y.

that, despite this flood flow during the construction of the dam, the contractors had to pump water for the concrete for a distance of 4 miles.

Right here the writer wishes to acknowledge the valuable services rendered him in the original Le Roy water system installation by a consulting engineer of this famous city, of Niagara Falls, Mr. Walter McCulloh who addressed this Assembly yesterday.

Le Roy's initial gravity supply constructed in 1916 was designed to furnish 700,000 gallons of water a day and while Le Roy has shown a very appreciable growth in the intervening 15 years, in 1930 the year of the severe drought which we all recall, the supply carried the village through and the officials estimate that at times the consumption for 1930 was in the neighborhood of 1,000,000 gallons a day.

After 15 years of operation with constantly increasing revenues Le Roy's gravity water system has reached its capacity which necessitates increasing the present supply. This will be accomplished by an additional storage dam now under construction seven miles south of the original reservoir. This will create a reservoir with a capacity of 160,000,000 gallons and has a tributary catchment area of 2.3 square miles. The earthen dam with a concrete core will have a maximum height of 36 feet and a length in the higher section of 500 feet and dykes which extend on one end for a distance of 550 feet and on the other end for 650 feet. The underlying shale comes to the surface and only a shallow trench was required to reach impervious material. The corewall of this dam, which is reinforced, is one foot thick on top and about 2 feet 8 inches thick on the bottom. From the dam a 10-inch cast iron pipe leads for a distance of 7 miles to the original storage reservoir. The improvements include increasing the capacity of the original filter plant and an additional pipe line laid in the village to increase the available pressure. This entire work is being rushed to completion and with continued good weather the additional structures will be operating this winter.

The tabulation of bids on Le Roy's new water supply, when compared with the prices obtained on the original supply some 15 years ago, coupled with the rate of interest of 3.85 percent on the sale of the bonds show beyond doubt that the present is indeed a favorable time to undertake the construction of municipal water works.

In 1916 the earth excavation at the Le Roy dam was bid at 40 cents a cubic yeard, whereas the price bid July 22, 1931 is 30 cents. The 1916 price for laying 14-inch cast iron pipe with lead joints,

including the hauling, excavation of trench and backfilling was 47 as compared with 35 cents a foot, with a joint compound instead of lead, in 1931. Incidentally the price for laying 30,000 lineal feet 10-inch cast iron pipe, including, hauling, excavation and backfilling of trench, was 33 cents a foot in 1931. The price bid this year for 14-inch cast iron pipe Class 100 was very little more than the price bid per foot on Class B pipe selling on a tonnage basis in 1916.

TICONDEROGA WATER SUPPLY

Ticonderoga, in common with many other villages and cities on the edge of the Adirondack Mountains, has available sources of water supply from practically uninhabited catchment areas covered with forest, from which flow streams of water entirely different from the streams which drain the cultivated farm lands of Western New York.

Ticonderoga is unusually well situated with respect to available water supplies. Lake George water pumped and filtered would give them a supply of good water. There are other places where dams could be constructed and the water brought to Ticonderoga by gravity. Nature has fortunately provided for this community one of the most ideal water supplies anywhere in existence.

Located about 8 miles west of the Village and about 7 miles from an existing reservoir now used as an emergency supply is Goose Neck Pond. Goose Neck Pond is one of those rare deep Adirondack Mountain lakes with steep rock sides, with no one living on the catchment area. The catchment area is covered to a large extent with evergreens and the water is soft and clear as crystal. This supply is truly a perfect water supply. All that the Village of Ticonderoga needs to do is to tap this natural reservoir at a sufficient depth below the surface to utilize the storage already created. The catchment area of Goose Neck Pond is approximately one and one-tenth square miles. It will be possible to utilize a total storage in both these ponds of 375,000,000 gallons. This amount of storage is so great that Ticonderoga need never fear a shortage of water. Goose Neck Pond is approximately 800 feet above Ticonderoga. From the Pond to the Village there is not a uniform down grade and for this reason the first five miles of the pipe line will be 14-inch. From then on, where the grade breaks rapidly a 10-inch pipe will be used. This 10-inch pipe will discharge into a new 1,000,000 gallons concrete lined distributing reservoir, at which point the water will be aerated. The water from this new distributing reservoir will lead directly into the present supply mains of the village.

This new supply will furnish the village of Ticonderoga 1,200,000 gallons a day. The amount of the bond issue is $195,000. Bids have been received well within the estimate and the work is now under construction. When this supply is constructed and completed the Village of Ticonderoga will have a water supply second to none in the United States. Not only will it supply an adequate quantity of pure, soft water under sufficient pressure, but the interest and annual cost of this proposed improvement will be less than the present cost of pumping. Rarely is a community so situated as to be able to take advantage of such an excellent opportunity to secure a new water supply.

CONTAMINATION OF GROUND WATER BY IMPOUNDED GARBAGE WASTE[1]

By C. K. Calvert[2]

The Indianapolis Sanitation Plant consists of a sewage disposal plant and a garbage reduction plant, located on the same property and adjacent to each other. A common power plant serves both the sewage and garbage plants with electric power for operation and steam for processing.

The water supply for boiler use, as well as for condenser water, (all power units being full condensing), is derived from wells. These wells are located 200 feet apart in an area just north of the power plant. They are approximately 80 feet deep and take their water from a gravel stratum, which lies on limestone approximately 100 feet below the surface. Additional water, of about the same mineral content and temperature, is obtained from an old gravel pit some 500 feet from the well field.

At Indianapolis the garbage is disposed of by cooking in steam jacketed pressure cookers, after which the free grease and liquor are withdrawn and the cooked garbage dried in the same container under vacuum. The tankage so obtained is percolated to recover grease and separated into two grades for fertilizer base and animal feed.

The liquor drained from the cooked garbage is put through a separating tank to remove the grease and is then ready for disposal, it being of insufficient value to warrant the recovery of its constituents. It amounts to from 15,000 to 30,000 gallons per day, depending on the quantity of garbage cooked. Its B.O.D. is extremely high. At full capacity it equals about 10 per cent of the total organic load of the sewage from the entire city, but on account of its large content of organic acids and salts, as well as carbohydrates, it is extremely difficult to treat by the activated sludge process and represents actually a greater load than its B.O.D. would indicate. The high concentration of organic matter makes it extremely unwise to deliver

[1] Presented before the North Carolina Section meeting, November 3, 1931.

[2] Superintendent, Sewage Disposal Plant, Indianapolis, Ind.

it directly to the stream. In the summer of 1930 it was decided to impound this liquor in an earthen reservoir during the low water period, with the expectation that it could be discharged to the stream without damage during flood stage.

A pit was constructed near the garbage disposal pant and about 500 feet away from the nearest well. It was known that the general direction of flow or ground water is from northwest to southeast. The location of the pit was directly west of the nearest well and southwest of the general group of wells. The garbage liquor contains from 1,000 to 2,500 p.p.m. of suspended solids, and from previous experience it was believed that this material would seal the bottom of the pit so that leakage would be almost negligible. Both on account of this sealing effect of the solids in the garbage liquor and the direction of flow of ground water it was believed that no contamination of the water supply would occur.

TABLE 1

Mineral content of garbage liquor, p.p.m.

Ca	663
Mg	182
Fe	246
Al_2O_3	874
Chloride (Cl)	2,950

However, about eight months after the impounding pit was put into use the effect of garbage liquor contamination was noted in the nearest well and in less than a month it was found in the second well.

Garbage liquor is dark brown with a specific gravity of approximately 1.04 and contains about 10 percent solid matter on evaporation. The solid matter contains about 10 percent ammonia. Its acidity, expressed in equivalent $CaCO_3$, varies from about 3,000 to 3,300 p.p.m.

One sample examined contained the minerals noted in table 1.

The chloride figure indicates that the well water contained about 9 percent of garbage liquor.

The ground water before the contamination occurred was quite hard. Its mineral content is shown in the first column of table 2. After the contamination occurred the mineral content changed, as is shown in the second column.

The gravel underlying this area is approximately 40 per cent acid soluble and contains both calcium and magnesium.

It was expected, therefore, that the calcium and magnesium content of the water, as well as its hardness, and residue on evaporation, would be increased considerably on account of the action of the acid garbage liquor on the gravel and by the large amounts of calcium and magnesium contained in the liquor itself. The examination shows this to be true, but the very surprising increase of the temporary hardness with only a moderate increase of the permanent hardness was quite hard to explain.

TABLE 2

Well water before and after contamination by garbage liquor

	PARTS PER MILLION	
	1923	1931
Fe	1.5	12.0
Ca	84	106
Mg	26	87
SO_4	36	Tr.
Cl	6	265
TH	280	800*
PH	42	68
TS	334	1,412
CO_2	20	330
T.O.N.†	0.2	18

* Alkalinity—the total hardness by soda reagent is 567 p.p.m.
† Total organic nitrogen.

It was expected that the iron and aluminum would go out of solution as alkalinity is established. The aluminum was not determined, but the iron figure indicates that some 50 percent of that in the original garbage liquor has been lost.

The experimental work reported here is quite meager and if time permitted should be extended to answer definitely the questions raised by these observations. The deep color of the garbage liquor interferes with titrations even when outside indicators are used and figures reported are approximations only.

It is known that calcium acetate reacts with soda reagent in the same way as the sulphate and chloride. No actual experiments have been made to determine the effect of other organic salts of cal-

cium. While it would appear that any non-carbonate, soluble calcium or magnesium salt should behave toward the soda reagents in the same fashion, it was learned from a pharmaceutical chemist that most of the organic salts of calcium can not be precipitated by sodium carbonate. It is suspected, then, that similar salts of magnesium will behave in the same way. This will explain the absence of permanent hardness.

On the basis of a 9 percent contamination, the calcium and magnesium from the garbage liquor are the equivalent of 217 p.p.m. expressed as $CaCO_3$, while the difference between the total hardness by soda reagent, and the total calcium and magnesium in the well water, is only 54 p.p.m. Obviously, calcium and magnesium have not come into the well as organic salts in the same proportion as the

TABLE 3

Effect of garbage liquor on gravel, p. p. m.

	FRESH LIQUOR	DAYS					
		4	7	11	14	18	20
Acidity*	2,950	1,500	950	800	0	0	0
Alkalinity*	0	0	0	0	375	625	750
Calcium (Ca)	663	1,069	1,326				1,657
Magnesium (Mg.)	182	207	209				236
Iron (Fe)	246	254	243				264
Al_2O_3	874	901	992				935

* In terms of $CaCO_3$.

chlorides. All bacteriologists consulted discourage the idea that bacteria would utilize the carbon in organic calcium salts, but this seems a good way to explain their disappearance.

The increase in calcium and magnesium may have come about by the solvent action of CO_2 produced by the action of the acid garbage liquor on the gravel. The contaminated water, as shown in table 2 did contain a large amount of free CO_2, although it would seem that it had ample time to act on calcium and magnesium in the gravel.

If the acidity of the garbage liquor is considered, and continuing on the assumption that 9 percent of the contaminated well water was garbage liquor, there is no explanation, so far, to cover the loss of calcium and magnesium. Bacterial action might leave the calcium as the insoluble carbonate, but with the large CO_2 content it should have gone into solution again.

In an attempt to duplicate the conditions in the ground, garbage liquor was poured over natural gravel in sufficient quantity to completely submerge it. The temperature was maintained at 20°C. The liquor was examined at the start and subsequently up to 20 days, as shown in table 3.

The decrease in acidity is perfectly easily explained, and the eventual establishment of a considerable alkalinity may be explained on the basis of the carbon dioxide liberated by the action of acid on calcium and magnesium carbonates. This explanation is felt, however, to be rather far fetched and it is believed that bacterial action must enter in, to a very large degree. The calcium and magnesium increase from fresh garbage liquor to that at the end of 20 days is not sufficient to account for the change in acidity. Had it been carried further, bacterial action would have proceeded so that the change in reaction and calcium and magnesium content might be found to be approximately the same. The liquor contained flocculent material at the end. It was not filtered before examination.

If bacterial action is responsible for the change in the condition of the calcium and magnesium the organism is one which will not grow on ordinary laboratory culture media.

The contamination of the water supply by the garbage liquor was so serious from the standpoint of hardness and organic content that it could not be used for boiler supply and in surface condensers. The contamination increased the biologic growth on condenser tubes and its chlorine demand was so high that large quantities of chlorine were required to retard growth. On this account its use was discontinued, the entire supply being taken from the gravel pit, which is a sufficient distance away to be unaffected by the garbage liquor.

SUMMARY

1. A serious contamination of ground water by impounded garbage liquor is reported, the effect being a large increase in the hardness of the water which, together with the high organic content, made it unfit for boiler and condenser purposes.

2. The total hardness is increased in the contaminated well water with very little increase in permanent hardness.

3. The suggestion is made that the increase in calcium and magnesium in the water is due to the action of organic acids on limestone and that the apparent change in the condition of the two may be due to bacterial action.

USE OF AMMONIA AT TAMPA WATER PURIFICATION PLANT[1]

By J. E. Lyles[2]

A water acceptable for drinking purposes and for general domestic and industrial consumption must meet the following requirements:

1. It must be hygienically safe,
2. It must be reasonably soft,
3. It must be practically colorless,
4. It must be free from objectionable odor and taste.

Methods and apparatus for producing a water that meets the first two of these requirements have been in use for a considerable period and water works practice in this field has become well standardized. Of late years the problem of eliminating red and discolored water, due principally to corrosion of the distribution system, has been rather successfully solved. Odor and taste, however, have long been most troublesome and touchy subjects among chemists and engineers engaged in the purification of water and it is only recently that successful and economical methods of eliminating certain of the most troublesome forms of odor and taste have been developed.

The best method for the elimination of an unpleasant odor and taste depends, of course, upon the underlying cause of the odor and taste and no one method is applicable to all cases. Aeration has long been a successful and popular method of odor control and is one of the oldest processes of water purification. More recent developments for the prevention of odor and taste are treatment with chlorine, potassium permanganate, sulphur dioxide, filtration through activated carbon and treatment with ammonia. While ammonia was used in water purification by Mr. Joseph Race at the Ottawa, Canada, plant as early as 1915, the process has only recently been understood and appreciated. The application of this process in numerous plants throughout the United States has demonstrated its many advantages and the subject of this paper will be the results of the treatment of Tampa water with ammonia.

[1] Presented before the Florida Section meeting, April 2, 1931.

[2] Engineer, Water Purification, Water Department, Tampa, Fla.

TAMPA WATER SUPPLY

The Tampa water purification plant was designed by Nicholas S. Hill, Jr., Consulting Engineer of New York City and placed in operation in March, 1926. It is a comparatively small plant, with a rated capacity of 12 m.g.d., but a very modern one embodying the latest features of purification practice.

The supply is obtained from the Hillsborough River which changes seasonally and at times very rapidly, according to the rainfall, from a soft, highly colored water to one which is only slightly colored and fairly hard. Various intermediate combinations of color and hardness are also obtained, so that at times we need only to decolorize and occasionally only to soften, but quite frequently we must both soften and decolorize. During the latter periods it is at times more economical to soften before decolorization and at other times best results are obtained by first removing the color.

Acid is manufactured at the plant from sulphur and used with alum for adjustment of hydrogen ion concentration. Facilities to recarbonate before filtration when necessary, are also provided, carbon dioxide being obtained from the combustion of coke. Corrosion of the distribution system is prevented by carefully controlled treatment with lime after filtration.

Prior to our adoption of the ammonia treatment we were nearly always troubled by the presence of an unpleasant odor and taste which can best be described as swampy. During 1928 aeration was tried as a means to eliminate this taste and odor and proved successful on an experimental scale. During 1930 the odor and taste problem was again attacked and all known methods of eliminating odor and taste were investigated. Our investigation was soon narrowed to three processes, namely, aeration, filtration through activated carbon and treatment with ammonia. Of these three, treatment with ammonia gives promise of being the most satisfactory.

AMMONIA TREATMENT

During the latter part of May, 1930, an ammoniator was made and installed. This ammoniator consists essentially of a pressure reducing valve by means of which the cylinder pressure is reduced and held at 5 pounds per square inch and a calibrated orifice and manometer assembly for measuring the loss of head as the ammonia passes through the orifice. This ammoniator with only minor re-

finements has given accurate and satisfactory service for approximately ten months.

The first application of ammonia was made on May 23 and periodic treatments were applied between May 23 and June 4. The advantages of this treatment were immediately apparent and continuous treatment with ammonia has been given the water since June 4, 1930. The ammonia, 2 pounds per million gallons, is introduced into the water just after it is filtered, and just far enough ahead of the chlorine to assure an intimate mix. Lime is added just after the chlorine in amounts sufficient to maintain equilibrium between the alkalinity and free carbon dioxide, resulting in a pH of approximately 7.8.

Our treatment with ammonia has had three important results, any one of which alone would warrant its adoption. First, it has eliminated the swampy odor and taste. This was apparent immediately after the treatment was started. It is believed that this taste was due to a combination of chlorine and organic matter, since it was present when chlorine alone was used and the water absorbed large amounts of chlorine and disappeared when the chlorine was fixed as chloramine and absorption by the water was cut down. Uncombined chlorine measured as residual chlorine was not responsible, since no traces of residual chlorine could be detected in the distribution system. In order to facilitate the detection of a slight odor and taste, a small hydro-darco filter was constructed and a portion of the water was by-passed through this filter. All taste was eliminated by the hydro-darco, thus giving a standard water with no odor or taste with which the unfiltered tap water could be compared. A slight taste might not ordinarily be noticed, but when compared with the effluent of the hydro-darco filter, its presence was easily detected.

Second, it has resulted in more effective sterilization, eliminating after-growths in the distribution system. Weekly samples are taken from the distribution system for bacteriological analysis, three from elevated tanks, one from a three million gallon reservoir and one from the Municipal Hospital. Before the use of ammonia these tanks served as a breeding ground for bacteria and during warm weather the count was especially high. These tanks and the reservoir were accordingly occasionally sterilized with chloride of lime, since an increase in the residual chlorine at the plant was ineffective. Since ammonia has been used, however, we have been able, by main-

TABLE 1

Chlorine alone

MONTH	CHLORINE USED	RESIDUAL CHLORINE
	lbs. per m.g.	*p.p.m.*
February	16.6	0.22
March	14.2	0.19
April	17.1	0.32
May	16.0	0.26
Average	16.0	0.25

Applied chlorine	1.92 p.p.m.
Residual chlorine	0.25 p.p.m.
Loss by absorption	1.57 p.p.m. or 14 pounds per million gallons
Cost of chlorine per million gallons	$1.54

TABLE 2

Chlorine and ammonia

MONTH	CHLORINE USED	AMMONIA USED	RESIDUAL CHLORINE
	lbs. per m.g.	*lbs. per m.g.*	*p.p.m.*
June	5.5	2.1	0.31
July	5.6	1.9	0.39
August	6.3	1.9	0.42
September	5.0	1.6	0.40
Average	5.6	1.9	0.38

Applied chlorine	0.67 p.p.m.
Residual chlorine	0.38 p.p.m.
Loss by absorption	0.29 p.p.m. or 2.4 pounds per million gallons
Cost chlorine per million gallons	$0.54
Cost ammonia per million gallons	0.40
Total cost per million gallons	$0.94
Cost of sterilization with chlorine alone	$1.54 per million gallons
Cost of sterilization with chlorine and ammonia	0.94 per million gallons
Saving with ammonia	$0.60 per million gallons
Water treated per year	3,539,960,000 gallons
Saving per year	$2,123.97

taining a residual chlorine of 0.3 to 0.4 p.p.m. at the plant, to eliminate entirely these aftergrowths. In fact, by further increasing the residual chlorine, we can completely sterilize the distribution system without the development of odor or taste.

Third, it has resulted in a saving of approximately $2,000.00 per year in cost of sterilization. The average dose of chlorine for the period, February 1 to May 30, 1930 was 16 pounds per million gallons. This gave us an average residual after the water had passed through the clear water basin (approximately two hours retention) of 0.25 p.p.m. The loss by absorption in this two-hour period was 14 pounds of chlorine per million gallons, and the cost of sterilization with chlorine alone was $1.54 per million gallons. During the period, June 1 to September 30, 1930, we used an average of 5.6 pounds per million gallons of chlorine and 1.9 pounds per million gallons of ammonia. This gave an average residual of 0.38 p.p.m. after the water had passed through the clear water basin. The loss by absorption in this two-hour period was only 2.4 pounds of chlorine per million gallons and the cost of sterilization was $0.94 per million gallons. We thus saved $0.60 per million gallons, cutting our loss by absorption from 14 pounds chlorine to 2.4 pounds chlorine per million gallons, and at the same time maintain a higher residual. During the year 1929 we treated 3,539,960,000 gallons of water, so our total yearly saving in cost of sterilization is $2,123.97. The above data are shown by months in tables 1 and 2.

EXPERIMENTS WITH HYDROGEN SULPHIDE WATERS

The writer has also conducted some experiments on a hydrogen sulphide well water in order to determine whether or not ammonia would reduce the amount of chlorine required to sterilize such a water.

When a water containing hydrogen sulphide is treated with chlorine the hydrogen sulphide will react with the chlorine and in order to obtain effective sterilization enough chlorine must be added to neutralize the hydrogen sulphide and leave an excess of chlorine.

This well water contains 2.5 p.p.m. of hydrogen sulphide which will react with and render ineffective approximately 44 pounds per million gallons of chlorine. It was hoped that if this water were first treated with ammonia the chlorine would react with the ammonia instead of with the hydrogen sulphide, and as a result it would only be necessary to add enough chlorine and ammonia to form a reasonable dose of chloramine.

This water was accordingly treated with various doses of ammonia and chlorine, the ammonia being added first and tested for residual chlorine and reduction in bacteria. No residual chlorine could be detected and no favorable bacteriological results were obtained. It was evident that in the presence of both ammonia and hydrogen sulphide that the chlorine would react with the hydrogen sulphide rather than with the ammonia.

It was then thought that, if a solution of chloramine was first prepared and then introduced into the hydrogen sulphide water, the chloramine might not be decomposed by the hydrogen sulphide or might be stable for a period sufficient to effect sterilization. This procedure was accordingly tried with the same negative results.

It appears that, while ammonia is of great benefit in the treatment of a water of high chlorine demand, due to organic matter, it will not reduce the chlorine demand when due to hydrogen sulphide.

COST KEEPING AND BUDGET CONTROL[1]

By F. M. Faude[2]

Practically all water works officials now recognize the value of accurate records of cost on construction work and for some items of operating expense. The present attitude is in marked contrast to that of only a comparatively few years ago when many of these officials thought that cost keeping was a needless expense.

Due to the present almost unanimous belief that cost keeping is an important aid in the construction of new facilities and in the operation of the water works plant, an attempt will not be made to demonstrate the value of cost records, but to point out some of the deficiencies of the present methods employed and some of the reasons for failure to derive the greatest possible benefit from the records.

Proper cost keeping is not a mere compilation of figures for transfer to the accounts of the municipality or corporation operating a water system, but, on the other hand, is the preparation of statistical data which may be of great and far-reaching value if careful study and analysis is made of the records after their completion. In the final analysis proper cost keeping, and its application to the problem of improving methods of operation and construction, is an art.

Some water works officials regard cost keeping as the exclusive function of the accounting department. Others believe that it is entirely an engineering function. Those who are so fortunate as to have had experience which includes some knowledge of accounting, engineering, construction, and plant operation and management, recognize and freely acknowledge that proper and accurate records of cost can be secured only by the closest and most interested coöperation of store keepers, foremen, superintendents, accountants, engineers, and plant managers. The plant manager has the most important and difficult portion of the work, for it is he who must harmonize and coördinate the activities of the various departments in order that accurate results may be obtained.

[1] Presented before the California Section meeting, October 30, 1930.

[2] Vice-President, The Loveland Engineers, Inc., San Francisco, Calif.

Cost records should always include statements detailing any unusual conditions encountered during the work which result in costs which are either higher or lower than fair average costs for similar work, or costs which are either higher or lower than the estimates of cost prepared prior to the beginning of the work. Without such explanations cost records lose much of their value.

A serious mistake is sometimes made when cost records are prepared by including only direct costs, such as materials and labor, in the totals, and omitting the indirect costs including administration, accounting, office expense, compensation and other insurance, use of company trucks, and automobiles, etc. It is sometimes difficult to prorate and apportion indirect costs to a particular job, but it should be remembered that indirect costs are frequently a very substantial portion of the total cost of the work, and this is especially true of small jobs. All cost records should list each indirect cost separately and if any are omitted a statement setting forth the reason for such omission should be included. In no case should indirect costs be lumped in one sum.

One of the greatest aids to accurate cost keeping is a requirement that no construction work shall be commenced, except in an extreme emergency, until a work order has been prepared and approved by the plant manager, or some other official having authority. The work order should describe the work in sufficient detail so that a check can be made as to its extent, location, the character of the materials to be used, and a description of the facilities to be replaced, if any. The work order should also include an estimate of cost. Appropriate blanks should be provided on the work order so that the quantities and costs of material, the wages of labor, indirect costs, and explanatory notes, can be entered. A sketch of the proposed work should be included on, or be attached to, the work order. The work order is, therefore, not only an authorization for the proposed work, but is also the basis for an accurate cost record, and affords an opportunity for a comparison between actual and estimated costs. In cases covering emergency work the order should be made out as soon as possible after verbal authorization has been given. Verbal authorizations should never be tolerated unless absolutely necessary.

The most serious objection to the verbal authorization is that it permits the "slipping in" of other work, not originally contemplated, until in some instances the authorization is expanded far beyond its original intent. The result is invariably a concealment of costs in an attempt to cover up.

Accurate cost records require expenditures which are sometimes objected to and attempts are frequently made to reduce the expenditures. This practice usually results in an impairment of the value of the records. It sometimes happens that very elaborate cost keeping methods are employed and that unnecessary refinement is sought. In such instances the costs of keeping the records are, naturally, unreasonably high. If, however, costs are kept within reasonable limits it will be found that the value of the records will far outweigh the cost. Careful study of cost records will frequently recult in improvement of working methods and a consequent reduction in construction or operating costs. It should be borne in mind, always, that you cannot get something for nothing, and that the making or saving of money almost invariably requires some expenditure before the desired results can be obtained.

The use of the budget system has gained so steadily in popularity that it is now regarded as an essential cog in the operating machinery. The main object of the budget is to secure control of expenditures, and some of its advantages are as follows:

1. Plant managers and other officials have definite goals to attain.
2. Expenditures are coördinated with financial resources.
3. Costs can be used for control rather than as historical data.
4. Reduction of waste is encouraged.
5. Responsibility for expenditures is definitely assigned.
6. Being based upon the revenue cycle, the budget gives warning of when to be cautious with expenditures.
7. The budget serves as a measuring stick to compare actual performance with promises and estimates.

Some of the essentials of a budget system are:

1. Careful estimates of revenues based upon the experience of previous years with adjustments to conform with present conditions.
2. Careful estimates of operating expenses based upon the same considerations as were employed in preparing the estimates of revenue.
3. Careful gauging of material requirements.
4. Provision for funds to carry through projected improvements.

Budgets must of necessity be flexible. Revenues may drop for some causes entirely beyond control and in such instances it may become imperative that budgeted expenditures be deferred or abandoned. On the other hand revenues may exceed estimates and permit the authorization of expenditures not originally contemplated.

Having been prepared and authorized, however, the budget should be adhered to if it be at all possible, as nothing discourages honest effort so much as frequent readjustment of expenditures necessitated by changes in the budget.

The budget system will not accomplish the impossible. It will not produce profits in excess of reasonable expectations under prudent management. It should be regarded as an aid in securing the best possible results under the conditions prevailing.

The budget, once prepared and authorized, will not work automatically. Results should be carefully studied, and comparisons made of actual and estimated costs. Every effort should be made to improve construction and operating methods. The keeping of accurate cost records will permit absolute control of the budget.

SOCIETY AFFAIRS

THE MISSOURI VALLEY SECTION

The seventeenth annual meeting of the Missouri Valley Section was called to order by Chairman H. V. Pedersen in the Grill Room of the Hotel Eldridge in Lawrence, Kansas, at 10:30 A.M. on Thursday, October 29, 1931. There were 38 members and guests present. Mr. A. B. Weaver, President of the Lawrence Chamber of Commerce, extended a cordial welcome on behalf of the City of Lawrence. Chairman H. V. Pedersen, General Manager of Water Works at Marshalltown, Iowa, responded to the address of welcome and expressed the thanks of the Section for the hospitality extended by the Chamber of Commerce and the public officials of Lawrence.

Chairman Pedersen then introduced Mr. R. L. Dobbin, President of the American Water Works Association, who expressed his pleasure in being present at the meeting of the section. Mr. Dobbin's presence, his kindly interest and advice in transacting the business of the Section added much to the value of the meeting.

The Chairman then announced the appointment of the following committees:

Auditing Committee: Chairman, George A. Nelson, Superintendent, Water Works, Boone, Iowa, and John C. Detweiler, Construction Engineer, Metropolitan Utilities District, Omaha, Nebraska.

Resolutions Committee: Chairman, Jack J. Hinman, Jr., Associate Professor of Sanitation, University of Iowa, Iowa City, Iowa; Otto S. Reynolds, Water Works Engineer, Kansas City, Mo.; F. M. Veatch, Consulting Engineer, Kansas City, Mo.

Topics listed on the program for Round Table Discussion were then taken up. Topic 1, "Should water works departments curtail their construction programs during this period of economic depression?" was discussed by John C. Detweiler; Geo. J. Keller, General Manager, Iowa Water Service Co., Iowa City, Iowa; Joseph S. Nelson, Commissioner of Water Works, Sioux Falls, So. Dak.; J. Chris Jensen and Thomas Maloney, Water Works Trustees at Council Bluffs, Iowa; William Molis, Superintendent of Water Works, Muscatine, Iowa;

H. V. Pedersen; and Thomas J. Skinker, Engineer in Charge of Distribution, St. Louis, Mo. The consensus of opinion was that the water works departments should not curtail their construction programs at the present time. In most instances reported the department was planning for the employment of more than the usual amount of labor, eliminating machines in order to use hand labor, speeding up their programs and planning to use hand labor during the winter months. Mr. R. L. Dobbin gave a very interesting account of the methods in use in Canada to relieve the unemployment situation.

The discussion of Topic 2 was opened by Mr. William Molis and participated in by H. V. Pedersen; Fred Stuart, Water Engineer, Industrial Chemical Sales Co., Chicago, Illinois; Harry W. Badley, Water Superintendent Carroll, Iowa; Geo. S. Nelson; John C. Detweiler; and Earle L. Waterman, Professor of Sanitary Engineering, University of Iowa, Iowa City, Iowa. It was brought out in the discussion that the effects of drought during the past summer had been to cause trouble in surface water supplies due to increased concentration of pollution and an unusually heavy growth of algae. Ground water levels have receded and additional wells have been put down in order to furnish the demand where ground waters are the source of supply. It was pointed out that the effect of low rainfall on ground water was usually not felt for some time and that the present situation might be the result of drought conditions during the preceding year (1930).

Topic 3—"Should meter repair men working in the field work in pairs?" developed into a discussion of the frequency of testing meters. There did not seem to be any opinion that repair men need to work in pairs in the field. It was stated by Mr. Jensen that the 1,1000 meters on the Council Bluffs system were tested every two years. Mr. Keller reported that after testing 600 meters in Iowa City and finding very little need for such testing, the program for systematic meter testing was abandoned.

In opening the discussion on Topic 4—"Are expensive tabulated forms for annual reports of water works departments justified?" Mr. Joseph Nelson stated that extensive tables were not included in the reports issued by the Sioux Falls, South Dakota Water Works Department, but that the report was planned to tell the story of water works operation to the public. Messrs. Nolte, Detweiler and Jensen emphasized the fact that it was desirable to have water works data unpublished in annual reports as this provided a means of fulfilling

the many requests for such information. It was felt that such reports were well worth the cost of publication.

The afternoon session of Thursday, October 29, was called to order by Chairman Pedersen with 32 persons present. The following papers were present: "The Lawrence Water Purification Plant," by F. M. Veatch, Consulting Engineer, Black and Veatch, Kansas City, Mo.; "Operation of the Lawrence Water Purification Plant," by C. T. Hough, Water Superintendent, Lawrence, Kansas; "The Economical Advantages of the Combined Operation of Water and Light Plants," by James D. Donovan, Manager of Production and Distribution, Board of Public Utilities, Kansas City, Kansas; "Pollution Hazards of Ground Water Supplies," by H. S. Hutton, Wallace and Tierman, Newark, N. J.

Following the adjournment of the meeting at 5 P.M., Chairman Pedersen called a meeting of the Executive Committee of the Missouri Valley Section. Messrs. Pedersen, Brown, Nelson, Detweiler, Nolte, Keller and Skinker were present. A general discussion of the policy to be followed in the matter of selection of meeting places ensued. While no action was taken it was the opinion of the committee that meetings should be held in the following order: Northwest, Southwest, Northeast and Southeast districts.

Invitations for the 1932 meeting from St. Louis, Excelsior Springs and Sioux City were presented by the Secretary. It was moved by Keller and seconded by Detweiler that the Missouri Valley Section hold its next annual meeting (1932) in Sioux City, Iowa. The motion was unanimously carried. The meeting was adjourned.

Entertainment features consisting of a smoker on Thursday evening and a sight seeing trip to Haskell Institute and the University of Kansas on Friday morning, were enjoyed by those present. At 11 o'clock on Friday morning, October 30, there was an inspection of the Lawrence Water Purification Plant, following which luncheon was served at the plant through the courtesy of the Lawrence Water Department.

The afternoon meeting on Friday, October 30, was called to order by Chairman Pedersen at 2 P.M. The following report of the Nominating Committee was presented by Mr. W. Scott Johnson.

Chairman—H. L. Brown, Salina, Kansas.

Vice-Chairman—J. S. Nelson, Sioux Falls, So. Dak.

Directors: Iowa, George J. Keller, Iowa City, Iowa; Kansas, C. T. Hough, Lawrence, Kansas; Missouri, J. T. Bodkin, St. Joseph, Mo.,

Nebraska, J. C. Detweiler. Omaha, Nebr.; South Dakota, W. W. Towne, Waubay, So. Dak.

Section Representative on the Board of Directors, American Water Works Association, H. V. Pedersen, Marshalltown, Iowa.

The following papers were then presented:

"The Effect of the 1930 Drought on Public Water Supplies in Missouri," by W. Scott Johnson, Chief Public Health Engineer, State Board of Health, Jefferson, Missouri.

"High Turnover Among Municipal Water Superintendents," by R. E. McDonnell, Burns and McDonnell Engineering Co., Kansas City, Mo.

"Bond Issue Campaign for the New Lincoln Water Works Improvements," by D. L. Erickson, City Engineer, Lincoln, Nebraska.

"The Merits of Steel Pipe for Water Mains," by John L. W. Birkinbine, Consulting Engineer, Philadelphia, Pa.

"Cast Iron Pipe for the Transmission and Distribution of Water Supplies," by Philip Burgess, Consulting Engineer, Columbus, Ohio. In the absence of the author this paper was read by the Secretary.

Following the Annual Dinner held at the Lawrence Country Club on Friday evening, October 30, Mr. R. L. Dobbin, President of the American Water Works Association addressed the members and guests. Mr. Dobbin was introduced by Mr. J. J. Hinman, Jr., a Past President of the American Water Works Association.

The session on Saturday morning was called to order by the Chairman at 9:20 A.M. The following papers were presented:

"A Study of the Presumptive Test in Water Analysis," by Miss Cassandra Ritter, Bacteriologist, State Water Laboratory, Lawrence, Kansas.

"The Use of Activated Carbon in Water Purification," by F. H. Waring, Chief Engineer, State Department of Health, Columbus, Ohio. (This paper had been previously presented at a meeting of the Central States Section and with the permission of the author was read by Fred Stuart, Water Engineer, Industrial Chemical Sales Company, Chicago, Illinois.)

"Performance of Small Turbo Centrifugal Units," by S. A. Thompson, Chief Engineer and Frank Lawlor, Superintendent Citizens Water Co., Burlington, Iowa. (Read by title.)

"Notes on Aeration of Water by Two Different Methods," Jack J. Hinman, Jr., Associate Professor of Sanitation and Quintin B. Graves, Graduate Assistant, University of Iowa, Iowa City, Iowa. (Read by Mr. Graves.)

"The Colorimetric Determination of Magnesium," by Jack J. Hinman, Jr., Associate Professor of Sanitation, University of Iowa and Vernon B. Fleharty, Department of Chemistry, Geneva College, Beaver Falls, Pa. (Read by title.)

Following the reading of papers the annual business meeting of the Missouri Valley Section was held. The following report of the Auditing Committee was presented:

"We have examined the books of the Secretary-Treasurer and find all accounts correct.

"Balance on hand checking account, $270.22.

"Balance on hand savings accounts, $768.69.

"Total balance on hand, October 31, $1,038.91.

Respectfully submitted,
(Signed) GEO. A. NELSON,
Auditing Committee."

Upon motion, duly seconded, the report was accepted and ordered placed on file.

The Resolutions Committee submitted the following report which was formally accepted and ordered placed on file:

WHEREAS the Missouri Valley Section of the American Water Works Association is concluding its seventeenth annual meeting held in the city of Lawrence, Kansas, and whereas, the Section is deeply appreciative of the many courtesies extended to its members by the people of the city of Lawrence and by certain others,

Therefore Be It Resolved that the Section expresses its thanks to the individuals or groups concerned and directs the secretary to inform each of the following persons or organizations by special letter of the action hereby taken.

The city Commission of Lawrence, Kansas.

The City Water Board of Lawrence, Kansas, and especially Mr. J. L. Constant, Utility Commissioner; Mr. C. T. Hough, Superintendent of Water Works; Mr. M. C. Cannon, Plant Engineer; Miss Alma Michaels and the other employees of the Lawrence Water Works.

The Lawrence Chamber of Commerce and especially Mr. A. B. Weaver, President; Mr. George Hedrick, Secretary; Mr. M. V. Kent, Assistant Secretary.

Also Mr. W. C. Simons of the Lawrence Journal world; Mr. E. F. Abels of the Douglas County Republican; The Lawrence Country Club and its manager, Mr. E. E. Alexander.

Also Hotel Eldridge through its manager Mr. W. G. Hutson and his subordinate employees.

Also The Haskell Institute through its superintendent, Dr. R. A. Baldwin.

Also The University of Kansas through the staff of the State Water Laboratory including Mr. Earnest Boyce, Director; Mr. R. E. Lawrence, Acting Director; Dr. Selma Gottlieb, Chemist; Dr. Cassandra Ritter, Bacteriologist.

Also The Kansas Athletic Association and its director, Dr. F. C. Allen.

Be It Further Resolved that the appreciation of the Section be expressed for the untiring work of the local entertainment committee, especially the ladies' entertainment committee consisting of Mrs. C. T. Hough and Mrs. George Wetzel and the general committee Messrs. J. L. Constant, Geo. Wetzel, C. T. Hough, N. T. Veatch, Jr., John A. Strang and F. M. Veatch.

Be It Further Resolved that the Section express its pleasure at the presence at this meeting of Mr. Ross L. Dobbin, President of the American Water Works Association and it is hoped that he may find it possible to visit the Section again.

Be It Further Resolved that the Section express its cordial appreciation of the coöperation of the Kansas Water Works Association in making the meeting at Lawrence the success that it has been.

And Be It Further Resolved that the Section thank Messrs. W. T. Burch, Ira T. Collar, L. M. Medlenka, L. T. Sharp and J. A. Strang for the indefatigable way in which they ministered to the comfort of the section members at the smoker on Thursday evening.

Respectfully submitted,
Yours Resolutions Committee
OTTO S. REYNOLDS,
FRANCIS M. VEATCH,
PROF. JACK J. HINMAN, JR.

The report of the Nominating Committee was then taken up for action. There being no nominations from the floor a motion was made, seconded, and carried directing the Secretary to cast a ballot for the nominees. This was done and the nominees declared elected.

There being no further business the Seventeenth Annual Meeting of the Missouri Valley Section of the American Water Works Association was brought to a close at 11:30 A.M., October 31, 1931.

MEETING OF EXECUTIVE COMMITTEE

On call of Chairman H. L. Brown a meeting of the new Executive Committee was held immediately following the adjournment of the business session on Saturday, October 31, 1931, at the Hotel Eldridge, Lawrence, Kansas. Present Brown, Nelson, Hough, Skinker and Detweiler.

Earle L. Waterman of Iowa City, Iowa, was elected Secretary-Treasurer for the ensuing year.

The expenses of the Secretary in connection with the Lawrence meeting were authorized to be paid from Section funds.

The following motion was made, seconded, and unanimously carried: That the Executive Committee allow $100 to the Secretary for his services during the past year. This amount to be in lieu of the

Secretary's expenses to the meeting of the American Water Works Association.

Director T. J. Skinker made an informal report on his activities as Section Representative on the Board of Directors of the American Water Works Association during the past year.

The Executive Committee meeting was then adjourned.

EARLE L. WATERMAN,
Secretary.

THE CALIFORNIA SECTION

The Twelfth Annual Convention of the California Section was held at Stockton, California, on October 28, 29 and 30, 1931. The proceedings are briefly outlined below.

October 28, 1931. Registration and Review of Exhibits. Golf Tournament, Stockton Golf and Country Club.

October 29, 1931. Executive Committee Meeting. After some discussion the Committee's report regarding changes in the by-laws and the selection of the meeting place for the 1932 convention was prepared for presentation to the membership at the business meeting.

Water Purification Meeting. Meeting called to order by President Wm. W. Hurlbut, who introduced Dr. Carl Wilson, chairman of the meeting. The following papers were presented:

"The Use and Limitations of Ammonia in Water Purification," by Kenneth Brown.

"Progress Made in Activated Carbon Treatment of Water," by Carl Wilson.

"The Physics of Aeration," by W. F. Langelier.

1:00 P.M. Demonstration of Pipe Pushing Machine, Adjacent to Auditorium under supervision of Hydrauger Corporation, Ltd.

2:00 P.M. The meeting was called to order by President Wm. W. Hurlbut and an Address of Welcome was given by J. Carl Tremain, Mayor of the City of Stockton.

The papers were then presented as follows:

"Group Operation of Water Utilities," by E. B. Walthall.

"Value of Water Works Conventions to Plant Operators," by Miss Jane H. Rider.

Symposium Session on Ground Water Development Problems—

"Gravel Pack vs. Standard Type Water Wells," by Arthur Taylor.

"Factors in Determining Diameter of Water Wells and Type of Casing," by Morris S. Jones.

"Factors in Determining Diameter of Water Wells and Type of Casing," by A. A. Blakeslee.

"Colorado River Water Flow and Regulation," by C. C. Elder.

Symposium Session on Practical Distribution Problems—

"Specifications, Installation and Maintenance of Gate Valves," by C. E. Angilly.

"The Development of Interior Pipe Coatings and Their Function Where Iron Fixing Bacteria Are Encountered," by F. C. Langenburg.

"Sterilization of Distribution Mains," by L. L. Farrell.

"Cleaning of Distribution Mains," by Orla Casad.

6:30 P.M. Business Meeting. Address by President Wm. W. Hurlbut.

The report of the Secretary was received and adopted.

The report of the Treasurer was submitted and ordered audited and certified. Upon motion duly made, seconded and carried, the action regarding the reports was approved.

Upon motion duly made, seconded and carried, a vote of thanks was given the officers for their able and economical manner of handling the affairs of the Section, which resulted in showing a very substantial cash balance in the treasury. Mr. L. M. Anderson, Chairman of the Nominating Committee presented the following names for office for the year 1931–1932: Wm. F. Goble, President; R. F. Goudey, Vice-President; R. F. Brown, Secretary-Treasurer; E. W. Green, L. L. Farrell, Geo. A. Elliott, J. R. Barker, and Richard Bennett, members of Executive Committee.

Upon motion duly made, seconded and carried by the unanimous vote of the members present, the nominations were closed and the above named persons were declared elected. The report of the Executive Committee setting forth certain changes in the by-laws and recommending that Coronado be selected as the meeting place for the 1932 Convention, was read.

Upon motion duly made, seconded and carried by the unanimous vote of the members present, the recommendations as set forth in the Executive Committee's report were approved.

Upon motion duly made, seconded and carried, the following resolution was adopted:

"Whereas, Transition has taken from our midst one of our beloved members, Wilkie Woodard, whose companionship and friendship was greatly valued by each one of us, and whose efforts in the interest of the industry and activities with which we are associated was an inspiration to all of us, and we shall miss his friendly contact and helpful association.

Therefore, Be It Resolved, That the members of the California Section of the American Water Works Association do hereby express their deep sorrow and regret for the passing of their co-worker and friend, and do also hereby express to his family the sympathy of all the members of the organization.

Be It Further Resolved, That this resolution be spread upon the Minutes of the meeting, and that the Secretary be, and he is hereby directed to send a copy of it to the family of the deceased."

Upon motion duly made, seconded and carried, the following resolution was adopted:

Resolved: That this Convention has heard with sorrow of the illness of two of its members, Mr. J. I. Prugh and Mr. Philip Schuyler;

That the Secretary of this Section, as an expression of the sympathy of the members present, be instructed to send them flowers and a copy of these resolutions with the sincere best wishes of all members present for their early recovery."

Senator Bradford Crittenden delivered a most interesting talk on the subject "State Program of Water Development." Mr. George W. Hawley also spoke on the subject "State Supervision of Dams."

In response to the request of Senator Crittenden it was moved, seconded and carried that the California Section of the American Water Works Association go on record as favoring the State Program of Water Development and is willing and anxious to use its influence to further this movement.

October 30, 1931. Demonstration of Efficiency Test of Deep Well Turbine Pump at Plant of Sterling Pump Company under supervision of H. A. Harris, Engineer, California Water Service Co.

The following papers were then presented.

"What's New in Water Purification," (Illustrated), by R. F. Goudey.

"Standardization of Specifications for Materials and Equipment," by Fred M. Randlett.

"Increasing the Capacity of the Owens River-Los Angeles Aqueduct," (Illustrated), by James E. Phillips.

"Corrosion in Neutral Waters," by Ira D. Van Giesen.

"Modern Service Installations," by H. A. Harris.

Symposium Session on Meeting Emergency Drought Conditions.

Discussion by M. R. Mackall.

Paper—by V. E. Trace.

Paper—by Thomas Willard Espy.

"Water Production Measurement Methods," by L. S. Hall.

"Necessity for Roofs on Service Reservoirs," by Peter Diederich.

"Have Our Meter Reading Sections Overlooked an Opportunity?" by O. C. Whitaker.

"Construction and Operation of the Chenery Reservoir of the California Water Service Company, Contra Costa County, California, by E. K. Barnum.

5:00 P.M. President Wm. W. Hurlbut announced that the business of the Convention was now brought to a close and the meeting adjourned, to be followed by the Exhibitors' dinner dance and entertainment at 6:30 P.M. and the Boat Trip and buffet luncheon as guests of the California Water Service Company at 11:00 A.M. on the following day.

6:30 P.M. Members and Guests were entertained by the American Water Works Manufacturers Association at a dinner dance held at the Stockton Civic Memorial Auditorium, at which time the prizes were awarded to the winners who participated in the Golf Tournament held at the Stockton Golf and Country Club on Wednesday, October 28, 1931.

October 31, 1931. Members and Guests were entertained by the California Water Service Company on a boat trip and buffet luncheon down the San Joaquin River, returning to Stockton at 4:00 P.M.

E. W. Green,
Secretary.

ABSTRACTS OF WATER WORKS LITERATURE[1]

FRANK HANNAN

Key: American Journal of Public Health, 12: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

Financing Municipally Owned Water Works Systems. HOWELL WRIGHT. Eng. News Rec., 104: 861–2, May 22, 1930. Fundamental principle to be followed in financing municipally owned water works is, that they should be self-supporting but not called on to support other branches of municipal services, or to produce a profit to be used in reduction of general taxation. Other prime essentials are budgetary control, including long-time program for capital outlays. Capital account should theoretically include all assets used in business which have life of 2 or more years. Ideal method of financing a public utility is the "pay as you go" plan. Profits from sale of product should be reinvested in the business, e.g., by retiring bonds, or by using the money for extensions and thereby eliminating borrowing. Financing of assets used in supplying other municipalities is not easy. Theoretically, sufficient profit should be made from each municipality supplied to pay for all such present and future assets. This is not always practicable; as rate on this basis might be prohibitive, resulting in little or no sale. Largest amount collectible should therefore be charged and balance collected later either through high rate-schedules, or high stand-by charges. Municipality should be charged irrespectively for all water used; water consumers should not be called upon to pay for water used for city purposes. Most equitable method of charging for water is step-down rate for large usage, as increased consumption of any commodity automatically reduces unit cost. Brief details are included on preparation of a budget, which should contain careful estimate of income and expense based upon experience of past years. Long-term programs of capital expenditures are of greatest importance.—*R. E. Thompson.*

Four Large Water-Filtration Plants Proposed for Chicago. Eng. News-Rec., 104: 815, May 15, 1930. Address by LORAN D. GAYTON before Western Society of Engineers outlines tentative plans for purification of Chicago water supply. Four filtration plants are proposed, to serve as many water supply districts through 12 pumping stations. Capacities are based on an unmetered dis-

[1] Vacancies on the abstracting staff occur from time to time. Members desirous of coöperating in this work are earnestly requested to communicate with the chief abstractor, Frank Hannan, 285 Willow Avenue, Toronto 8, Ontario, Canada.

tribution system. Most of pumping stations are already in service. Estimated cost to serve present population is $60,000,000. Filtration plants would be in units consisting of mixing and settling basins of 55-minute and 4-hour detention capacities respectively, sedimentation in two stages, sand and activated carbon filters of 144-million gallons per day capacity, operating at rate of 125 million gallons per acre per day, and 10 million gallons clear-water storage. Main facts brought out by work at Chicago experimental filter plant and studies of design division include following. (1) Lake Michigan water may be made perfectly clear and potable by filtration at cost similar to that incurred in other cities. (2) Most desirable method of treatment will include partial softening, saving soap to extent of $750,000 annually. (3) Cost of filtration will not exceed $1 per capita per year; it would cost the citizens 10 times as much to buy spring water for actual drinking purposes ($\frac{1}{4}$ gallon daily). (4) Based on initial outlay of $60,000,000, sinking fund, operation, and maintenance charges would add only 2¢ per 1000 gallons to cost of supplying water. This could be met by increasing present low rate of 6$\frac{1}{4}$ cents per 1000 gallons to 8$\frac{1}{4}$ cents. (5) Alum produces excellent clarification but, when microörganisms are abundant, filter runs are too short for practical and efficient operation. (6) Ferrous sulfate and lime give good results and produce runs within limits of what may be considered satisfactory practice. (7) Chlorinated copperas and lime produce excellent results and give filter runs long enough for practical operation. (8) Superchlorination followed by dechlorination with activated carbon removes all objectionable taste-producing compounds likely to occur in Lake Michigan water. (9) Rates of filtration in excess of those customarily employed may be used, with consequent saving in construction which will exceed total expenditure on experimental work. (10) Mixing period of at least 45 minutes has been established as necessary to produce the most efficient results.—*R. E. Thompson.*

Everett Averts Water Famine. G. G. Paine. Eng. News-Rec., 104: 863–4, May 22, 1930. City of Everett, Washington, faced serious water famine during extremely cold weather of January, 1930 when that portion of its 28-inch supply line above ground gradually froze until normal supply of 10 million gallons per day had decreased to something less than 3 million gallons per day. On January 15th it was realized that it might be necessary to pump water from Pilchunck River at point where the supply line crosses it, there being no ice in the line from that point on. An emergency pumping unit of 2 five-stage centrifugal pumps connected in series and direct-connected to one 650-h.p. motor, pumping against 450-foot head, was installed, together with oxyacetylene-welded pipe system connected to supply line, all of which was completed and put in service at 6 a.m. on January 19th. That evening, after repairing faulty check valve, 8 million gallons per day was being delivered into supply line. Fire pumps had been in use since previous morning. Owing to high consumption due to broken services and taps left running to prevent freezing, a second unit was installed and was in operation on January 23rd, the two then delivering about 13 million gallons per day without aid of fire pumps. —*R. E. Thompson.*

Flood Overflow on Calderwood Dam Scours Deep Into Rock. Eng. News-Rec., 104: 1064–5, June 26, 1930. Illustrated data are given. Calderwood Dam of the Aluminum Company of America is on Little Tennessee River. When 20-day flood overflow subsided it was found that a hole about 30 by 50 feet and 50 feet deep had been scoured out of the rocky river bed 75 feet downstream from toe of dam. Free fall of water was 185 feet. Dam is a high arch concrete structure of full overflow type, with gravity dam situated a short distance downstream from the arch to create a cushion pool 40 feet deep to receive overflow. In addition, overflow jet is to be tempered by heavy concrete bucket deflector built in river bed along line where main overflow will strike. Base of dam is protected by concrete armor. Main structure was completed by April 15th and river diversion gate closed, permitting reservoir to fill. Completion of cushion pool dam and deflector had been purposely delayed to permit of their construction without cofferdams. On May 11th, flood of unexpected volume occurred, spilling continuing until May 31st, reaching estimated maximum flow of 10,000 second-feet. Rock is laminated and folded, and more susceptible to scour than a solid formation. Foundations of dam extend down to elevation of about 15 feet above bottom of hole. Hole was filled with concrete and completion of cushion pool dam and deflector is now under way.—*R. E. Thompson.*

Progress and Trends in Water Softening. Charles P. Hoover. Eng. News-Rec., 104: 843–6, 1930. In 1929, approximately 110 municipalities in the U. S. softened their water supplies, 98 employing lime, or lime-soda, process and 12, zeolite methods. Carbonate hardness of any type of water can be reduced, irrespective of temperature, to approximately the theoretical limit, i.e., to less than 20 p.p.m., by excess lime treatment and carbonation. Lime is the cheapest method of removing carbonate hardness; non-carbonate hardness can be reduced more economically by base-exchange than with soda ash. It is believed that the use of lime-zeolite process is justified when non-carbonate hardness to be removed is 85 p.p.m. or more. It has recently been demonstrated at New Bremen, O., that downflow softening with greensand will remove both Fe^{++} and Fe^{+++} from water, even after the capacity for removing hardness has been exhausted.—*R. E. Thompson (Courtesy Chem. Abst.).*

Power Possibilities of Catawba River Highly Developed Through Stream Control. Eng. News-Rec., 104: 1007–12, June 19, 1930. Description of system of Duke Power Company on the Catawba River, a flashy stream in North and South Carolina, which includes 9 dams, creating reservoirs having combined superficial area of more than 55,000 acres and total useful storage capacity approaching 42 billion cubic feet. Dam forming chief reservoir at head of chain is an earth-fill structure 165 feet high, one of highest of its type in the world. Other dams are of overflow concrete gravity-section type.—*R. E. Thompson.*

Locating Branches on Small Sewers. John W. Raymond, Jr. Eng. News-Rec., 105: 69, July 10, 1930. Brief illustrated description of device for locat-

ing branches in small pipe lines. The contrivance is hauled through the pipe from manhole to manhole, location of branches being indicated by the ringing of a gong. Over 1½ miles of pipe line was checked for branches in 6 days.—*R. E. Thompson.*

Water Softening Association Recommended for Education of Public. A. M. Buswell. Eng. News-Rec., 104: 846 (1930). An association of manufacturers of water softening equipment for education of the public regarding benefits of water softening is proposed. Not over 10 per cent of water supplies which, from economic standpoint, should be softened, are softened. In Illinois every public water supply should be softened, yet only 1 per cent of the municipalities have water softening plants.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Thirteen Men Killed in Two Tunnel Explosions. Eng. News-Rec., 104: 989, June 12, 1930. On June 9th, an explosion in the nearly complete water intake tunnel 180 feet below the surface of the Detroit river, killed 6 men and injured 6 others. It is believed to have been due to a charge of dynamite which had failed to explode when a section of heading and bench was shot by the night shift, being set off accidentally by day shift while mucking and clearing the bench. An explosion of natural gas on June 9th in the Calaveras tunnel of the San Francisco new water system resulted in death of 7 men. It is believed that a pocket of gas was ignited by a workman's drill. Depth of tunnel at point where explosion occurred is about 1 mile.—*R. E. Thompson.*

Holing Through a 6-Mile Tunnel on the Japanese Railways. I. Takemata. Eng. News-Rec., 104: 1062, June 26, 1930. The Shimizu tunnel, 6 miles long, was holed through on December 29, 1929. Large flows of water along faults were encountered during construction, amounting to 12 second-feet on south side and 10 second-feet on north side. About 11 second-feet gushed out from one spot when a big fault with much fault breccia was struck in November, 1927. Following this a drain tunnel, 7 by 7 feet in section, was driven to the water-bearing fault, some 9,000 feet from portal. Drain tunnel runs parallel to main tunnel, 50 feet away, and 4 feet below the formation level or subgrade.—*R. E. Thompson.*

Southfield Road Tunnel-Sewer Failures, Detroit, Michigan. Eng. News-Rec., 105: 15–7, July 3, 1930. Three serious failures in lower portion of recently completed Southfield Road sewer in Detroit are discussed. Great difficulties were encountered by contractors in tunneling through quicksand and quality of the work was quite unsatisfactory. The concrete is light, porous, and deficient in cement and thickness of lining is only from 12 to 15 inches, instead of 16 inches as specified. In opinion of investigating committee, failure was caused by infiltration into the sewer, through cracks and construction joints in concrete of poor quality, of ground water carrying with it great quantities of the surrounding extremely fine sand, resulting in impairment of the foundations and subsequent settlement. Probable manner of reconstruction is outlined.—*R. E. Thompson.*

Conservancy District on the Rio Grande. LEE NOFTZGER. Eng. News-Rec., 104: 968–71, June 12, 1930. Details given of project of Middle Rio Grande Conservancy District which includes flood control, irrigation, and drainage. Congress has authorized an appropriation of $1,593,000 on behalf of Indian lands and district has contracted for sale of $5,000,000 bonds out of an authorized issue of $8,744,000. Storage of 198,000 acre-feet for irrigation and partial regulation of river flow will be provided by a gravel and loose-rock dam on the Rio Chama 175 feet in height above bedrock and 1,300 feet long at crown and 140 feet at the bottom. Crown width will be 20 feet and maximum base width 600 feet. Upstream and lower faces will have slopes of 1 on $1\frac{3}{4}$ and 1 on $1\frac{1}{2}$, respectively, and former will be protected with reinforced concrete 8 inches thick at top and 13 inches at bottom, where it will join a concrete cutoff wall extending to bedrock. Foundations of wall will be grouted under pressure. Cost of reservoir is estimated at about $8 per acre-foot of storage. In addition, there will be 4 lower diversion dams.—*R. E. Thompson.*

Occurrence and Characteristics of Missouri River Cutoffs. F. Y. PARKER. Eng. News-Rec., 104: 1042–5, June 26, 1930. Discussion of river cutoffs, with particular reference to the Missouri River.—*R. E. Thompson.*

Studies of Biochemical Oxygen Demand of Trade Wastes. E. F. ELDRIDGE. Eng. News-Rec., 105: 12–3, 1930. Graphs are given showing the average total biochemical O_2 demand, determined by the dilution method, using RIDEAL-STEWART modification of WINKLER method for dissolved O_2, of 5 series of samples of various wastes from paper mills, milk plants, and beet sugar factories. Rate of oxidation of each of these wastes under similar conditions is quite varied and calculation of total O_2 demand from 5-day demand by formula given in Standard Methods of Water Analysis would lead to erroneous conclusions. An oxidation curve which would be generally applicable to trade wastes is not feasible. First-stage oxidation, in most cases, closely follows the formula curve; but the second stage does not take place at same time with the different wastes studied. This may depend upon pH of incubated sample. There are indications that nitrification occurs more rapidly in the more alkaline samples.—*R. E. Thompson (Courtesy Chem. Abst.).*

Pasadena Water Department Policy. Eng. News-Rec., 104: 867–8, May 22, 1930. The base rate for domestic use of water in Pasadena, Cal., is 13 cents per 100 cubic feet and for irrigation and municipal use, 6 cents. Minimum monthly rates, which vary with size of meter, are given. New services are charged for at following rates: $\frac{3}{4}$-inch, $15; 1-inch, $20; $1\frac{1}{2}$-inch, $25; 2-inch, $45. Where services are forced in ahead of street work, 10 per cent is added. Meters, other than for irrigation water, are supplied free. Since its organization in 1912, department has not received money from any source other than its normal revenue. Much construction has been provided for on this basis. Water is supplied to the city for fires and for flushing sewers free of charge, although water department pays for every service received from other city departments, including rental for space occupied in city hall. Earnings for

year 1929 were 7.43 per cent on the depreciated present value of the combined capital and current assets.—*R. E. Thompson.*

Developments in Water Purification Practice. HARRY N. JENKS. Eng. News-Rec., 105: 70, 1930. A brief discussion. It is now possible to reclaim from sewage a water supply conforming to the Treasury Department standards at a total cost substantially less than that required to develop an equivalent quantity from distant natural sources. Intermediate between the well-ordered mixing of coagulants and the semi-quiescence of sedimentation, there should be interposed a period of gentle stirring or streaming to produce agglomeration of the floc. This usually takes place at velocities ranging from 0.1 to 0.15 foot per second. The tank or channel capacity for this period is more than offset by the reduction in sedimentation basin size made possible thereby.—*R. E. Thompson (Courtesy Chem. Abst.).*

East Bay System Completed. F. W. HANNA. Eng. News-Rec., 104: 866, May 22, 1930. Completion of Mokelumne project to the point of delivering water to East Bay Municipal District in summer of 1929 enabled local supply reservoirs to be replenished just in time to avoid serious water famine. Main storage of 204,000 acre-feet is provided by Pardee dam. The outlet tower, 193 feet high, contains 15 gates in groups of 3, each group being capable of discharging 200 million gallons per day into aqueduct. The 95-mile aqueduct includes 4 tunnels with combined length of 9.3 miles, reinforced-concrete section 3.5 miles long, and steel pipe line 65 inches in diameter for remainder of distance. With present pumping plants, this conduit has capacity of 60 million gallons per day. Tunnels and concrete sections, however, have been designed for ultimate capacity of 200 million gallons per day and, when necessary, pipe lines will be added to make this flow available. Storage provided eliminates any possibility of future water shortage and quality of the water has consistently improved since Mokelumne supply was brought in.—*R E. Thompson.*

Largest Dams in the United States and Abroad. P. I. TAYLOR. Eng. News-Rec., 105: 104, July 17, 1930. Tabulated data given for highest and largest structures in United States and elsewhere.—*R. E. Thompson.*

Sanitary Conditions in China. CHARLES E. O'ROURKE. Eng. News-Rec., 105: 185–6, 1930. Briefly discusses sanitation in China with view to correcting wrong impression possibly created by BABBITT (cf. C.A., 24: 3302). Progress in sanitation has been more marked during past 5 years than ever before.—*R. E. Thompson (Courtesy Chem. Abst.).*

Progress in Control of Nile for Irrigation. H. E. BABBITT. Eng. News-Rec., 105: 206–10, August 7, 1930. Illustrated discussion of irrigation in Egypt, including descriptions of the first and proposed second raisings of the Aswan masonry dam and of construction of Nag Hamadi barrage now nearing completion. Latter structure, designed solely to increase height of flood peaks on Niles, will be 2700 feet long, exclusive of lock on western end,

and about 39 feet high above floor of foundation. Impervious portion of foundation consists of monolithic concrete slab, upstream and downstream aprons being made up of dry rubble covered with rubble masonry or concrete blocks. Models of irrigation structures in Egypt are studied at the hydraulic laboratory at Delta barrage. Future plans for irrigation works are outlined.—*R. E. Thompson.*

Tests of Models of Hastings Lock and Dam. WILDURR WILLING. Eng. News-Rec., 105: 87–8, July 17, 1930. Brief details are given of hydraulic laboratory studies, particularly on prevention of scour, being made in connection with Hastings dam now in process of construction on Mississippi River at Hastings, Minn.—*R. E. Thompson.*

Design of Monolithic Concrete Siphons Simplified by Use of Diagrams. J. J. DOLAND. Eng. News-Rec., 104: 1047–52, June 26, 1930. Illustrated description of methods employed by United States Bureau of Reclamation in design of inverted siphons for conveying water across depressions, or valleys. Examples are given of siphons which have been constructed.—*R. E. Thompson.*

Calibrating of Sixteen Triangular Weirs at Purdue University. F. W. GREVE. Eng. News-Rec., 105: 166–7, 1930. Tests carried out on 16 triangular weirs to determine relation of head to discharge are described and equations developed are given. The range in central angle was from 25° to 118° and number of tests conducted on each weir varied from 32 to 74, two tests being run for each condition of constant head.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

What Share of Flood-Control Costs Shall Federal Government Assume? E. W. LANE. Eng. News-Rec., 105: 9–11, July 3, 1930. General discussion, with particular reference to the Mississippi. It is believed that adoption by Congress of policy of paying fixed proportion of cost of local flood control works would solve problem of federal appropriations for such works.—*R. E. Thompson.*

Fabricating Fascine Mattresses for Mississippi Revetment. Eng. News-Rec., 105: 4–7, July 3, 1930. Illustrated description of methods of fabricating fascine mattresses, which consist of wire-bound bundles, or fascines, of willow brush strung side by side on wire cables and stiffened on top by lines of poles crossing the fascines and fastened to them. As the mattress is constructed it is anchored upbank by wire cables and then sunk by loading with stone.—*R. E. Thompson.*

Hydraulic-Fill Levee Construction on the Mississippi. JOHN R. WILBANKS. Eng. News-Rec., 105: 84–7, July 17, and 131–3, July 24, 1930. Data are given based on two years' levee work in Middle Delta Region.—*R. E. Thompson.*

Arc-Welded Steel Swimming Tank. Eng. News-Rec., 105: 256, August 14, 1930. Brief description of construction of new swimming pool at National Town and Country Club, Cleveland, which was completely fabricated by

electric arc-welding. Tank, which has capacity of about 300 tons of water, is approximately 75 feet long and 25 feet wide and extends from fifth to fourth floor of the building. It is lined with gunite and tile.—*R. E. Thompson.*

An Outbreak of Typhoid Fever at Gillam, Manitoba. F. W. JACKSON. Can. Pub. Health J., 21: 328–31, 1930. During April, 1930, 69 cases of typhoid fever, 8 of which proved fatal, occurred in and about Gillam, a divisional point on Hudson Bay Railway. Outbreak was traced to well on bank of Kettle River, with direct connection to river for use during low water. It was found that river had frozen solid some few hundred feet below sewer outlet, causing sewage to back up to well intake, about 1200 feet upstream. Closing of intake pipe, chlorination of well, and boiling of all water used from well immediately stopped the epidemic. Dam has been constructed above sewer outlet and chlorination has been continued. New well has also been constructed.—*R. E. Thompson (Courtesy Chem. Abst.).*

Short Gun Shoots Holes in Well Casing. P. S. MALAN. Eng. News-Rec., 105: 67–8, July 10, 1930. A new well in Cape Town, South Africa, yielded only 286 gallons per hour, it being obvious that casing had been driven past the water bearing strata and that water could with difficulty percolate through crevices in rock. Efforts to pull the casing were unsuccessful. A gun (illustrated) was devised by means of which 33 holes were shot into casing between 65- and 100-foot levels. As internal diameter of casing was only 6 inches, gun had to have overall length of not more than 5¾ inches. Cartridges employed were of 9.3 mm. Mauser type. The gun, which was operated under 27 to 62 feet of water, had to be repaired after every 5 or 6 shots. Yield was increased to 1600 gallons per hour.—*R. E. Thompson.*

Retaining Wall Costs Compared. Eng. News-Rec., 105: 331, August 28, 1930. Data obtained in designing 20-foot retaining wall are given. Costs for gravity, cantilever, and counterfort (various spacings) sections were compared. Cantilever type is shown to be most economical.—*R. E. Thompson.*

Mosquito Control at Saluda Dam. Eng. News-Rec., 105: 129–30, July 24, 1930. Mosquito control on shore line of more than 500 miles of 62,000-acre reservoir created by the Saluda dam in South Carolina is being effectively accomplished at nominal cost with limited amount of equipment and crew of 6 or 8 men. Maximum water depth, when reservoir is filled to spillway crest level, is 198 feet, length of reservoir at that level being 35 miles and maximum width 14 miles. Water level varies constantly. Larvae of all types of mosquitoes feed at or near surface of quiet water close to shore line and it is possible to kill them by spraying oil on the water a few feet from shore. Where dense growths of vegetation occur, effective oil distribution is difficult at times. Under such conditions Paris green is blown over surface so as to reach locations inaccessible to oil spray equipment. Since Paris green is effective only when ingested by larvae, while larvae of pest type feed below the water surface, reliance is placed almost entirely on oil treatment. Experience has shown that under the most favorable conditions it is necessary to destroy

larvae once a week. Details of equipment and methods employed are given. Oil used is mixture of commercial grades costing about 13 cents per gallon delivered. Kerosene is the destructive agent; heavy black lubricating oil serves as base; and light lubricating oil, known to trade as No. 1 paraffine, provides the desired distributive qualities. The 3 grades are mixed in equal proportions by refiner. Average ratio of oil to water employed for spray is about 1:100. The Paris green is mixed in proportion of 5 to 100 with hydrated lime. Spraying is carried out from boats with a barge as floating base.—*R. E. Thompson.*

Present Status of Potable Water Disinfection. E. HERRMANN. Pharm. Zentralhalle, 71: 97–9, 1930. From Chem. Abst., 24: 2218, May 10, 1930. Discussion of methods prevailing in certain continental districts, involving use of chloride of lime, chlorine, chloramine-T, etc.—*R. E. Thompson.*

Water-Station Reservoirs on the Illinois Central Railroad. C. R. KNOWLES. Eng. News-Rec., 105: 139–41, July 24, 1930. On the new 169-mile Edgewood cutoff between Edgewood, Illinois, and Fulton, Kentucky, there are 8 water stations, 5 of which are supplied from impounding reservoirs, 2 from deep wells, and 1 from a stream. The water supplies are described briefly, principal features of dams and reservoirs being tabulated. All dams are of earth-fill construction, with puddle or sheet pile cores to solid ground and reinforced concrete slab facings on water side.—*R. E. Thompson.*

Engineering Aspects of the Present Drought. Eng. News-Rec., 105: 259–61, August 14, 1930. Data are given on present drought in United States, which, in the wide areas affected, is said to be the greatest in American history. Proximate cause may be described as atmospheric stagnation, a widespread ceasing of normal circulation. Normally, low-water peak is not due until September, or even as late as November. Long-time records show that stream flow may be expected to fall off until autumn period of low water. No ordinary rain can do more than check this downward trend. Inasmuch as many streams have already reached their record low flows, it is almost certain that further recessions will bring about a lack of water such as has never been known in this country. Even if rainfall should return to normal, many streams will continue to fall due to depletion of ground water supply. So far, few cities have felt any great lack of water. With rivers so low, sewage pollution has been much more noticeable than in normal flow. Little definite information is available regarding depletion of water in underground storage. In general, government experts believe that season started with ample ground water supply, which has saved the situation so far. Observations show that trend of ground water levels in the United States is generally downward through the summer, regardless of rain. Next year, unless fall and winter precipitation is heavy, some areas may suffer owing to deficient ground water.—*R. E. Thompson.*

Power Development at Springfield Requires Intake Changes. Eng. News-Rec., 105: 168, July 31, 1930. Several important changes are being made in

municipal water supply system of Springfield, Mass., in order to make full use of power possibilities of Cobble Mountain dam. Water from Cobble Mountain will flow through a power plant with capacity of approximately 10 times average flow, so that the entire daily discharge will pass through plant in 2 or 3 hours. This large flow, after leaving power plant, must be carried through tunnel nearly a mile long for storage in existing reservoirs, to maintain domestic water supply at uniform rate. Tunnel, driven 20 years ago, is of sufficient capacity, but pipe connections at each end are inadequate. Contracts for driving 2 additional rock tunnels, 840 and 730 feet long, at Little River and at the filter plant respectively, have been awarded. Part of new work consists of installing 2 venturi meters, one 36-inch and the other 72-inch, which will accurately measure the flow at all times. These meters are combined with 2 Dow gates hydraulically controlled to shift the water so as to maintain accuracy of measurement. When flow exceeds quantity that will pass the 36-inch meter with reasonable loss of head, one gate will open and flow will be divided over both meters: when flow falls to point approaching that at which there would be failure to record accurately on both meters, this gate will close and the whole flow will pass through smaller unit. The second Dow gate is used as a throttling gate and is so connected as to back up pressure on either, or on both meters when water is unusually low, and to prevent flow in excess of combined capacity of the 2 meters. It will also close sufficiently to prevent loss of water over spillway of lower reservoir. Control of these units will be automatic, maintaining the conditions of water service without loss, regardless of discharge from power plant.—*R. E. Thompson.*

Additional Intake Works for Springfield, Mass. Eng. News-Rec., 105: 195, July 31, 1930. Additional intake works for Little River supply include construction of two rock tunnels, 840 and 730 feet long, and connecting them to present intake works between dam on Little River and filter plant at West Parish. Both tunnels are concrete lined and of cross-sectional area equivalent to circle 6½ feet in diameter. Outline of specifications on which bids were asked is given. Lowest bid, which was accepted, was $172,660, this bid being 18 percent below second lowest and 20 percent below average of 5 bids received. Tabulation of unit prices of two lowest bidders is included.—*R. E. Thompson.*

Measuring Rate of Glacial Flow on Mount Hood in Oregon. EARL A. MARSHALL. Eng. News-Rec., 105: 326–8, August 28, 1930. Data obtained by research committee of "The Mazamas," an Oregon organization of mountaineers, in their studies of ice flow in Eliot Glacier on Mount Hood. Investigations extending over 5 summers have shown (1) great differences in rate of ice movement at different levels; (2) that movement in winter is nearly as rapid as in summer, notwithstanding fact that flow of water from glacier is less and that no direct evaporation from the ice can occur; and (3) that as much as 20 feet of clear ice, in addition to the winter snow, may melt, evaporate, or otherwise disappear from the surface during a summer.—*R. E. Thompson.*

Blame Divided for Detroit Sewer Failure. Eng. News-Rec., **105**: 210–11, August 7, 1930. Data are given from report of committee investigating failures in Southfield sewer, Detroit. The 3 failures are attributed to removal of the foundation consisting of fine water-bearing sand which was carried into interior of sewer by ground water through faulty concrete construction joints and openings developing in sewer barrel after construction. Insufficient soil investigation, inadequate design, inspection, and supervision, together with faulty construction, were held to be contributing causes. Responsibility for failure is placed jointly on department and on contractor. Recommendations are made for reconstruction.—*R. E. Thompson.*

Design of River des Peres Drainage Channel, St. Louis, Mo. Eng. News-Rec., **105**: 124–8, July 24, 1930. **Constructing River des Peres Drainage Canal in Earth.** Ibid., 176–80, July 31. **Special Cost-Plus Contract for River des Peres Drainage Canal in Rock.** Ibid., 250–3, August 14. **Constructing Large Concrete Conduits for River des Peres Drainage.** Ibid., 296–300, August 21. W. W. Horner. Extensive description and discussion of River des Peres drainage channel now under construction, which will replace 18 miles of natural stream by 13 miles of structure intended to carry the stream flow conformably with general standards of sewerage in the city. Channel will consist of about 7.3 miles of open canal in earth, 1.7 miles of open canal in rock, and 4 miles of reinforced concrete arch conduit. Of concrete conduit, 10,000 feet will consist of twin arches, each 29 feet wide, remainder, of single arch 32 feet wide. Project was undertaken, at cost of $11,000,000 owing to damage created by flood overflows and to increasing pollution of the stream by sewage discharge.—*R. E. Thompson.*

Tilting Slab Flashboards Provide Emergency Spillway. Eng. News-Rec., **105**: 263, August 14, 1930. Brief illustrated description of concrete flashboards being provided for spillway of Dix River dam plant of Kentucky Utilities Co., which will automatically be released in event of unusually high water.—*R. E. Thompson.*

The Centrifugal Casting of Iron Pipes. E. J. Fox, et al. Proc. Staffordshire Iron and Steel Inst., **44**: 53–67, 1929. From Chem. Abst., **24**: 2091, May 10, 1930. Process of maufacturing 4- to 15-inch pipe by centrifugal method is detailed for plant making from 20 to 25 miles of pipe per week. Important factors in satisfactory production of centrifugal castings are: (1) speed of rotation; (2) rate of flow of metal; (3) rate of traverse; (4) casting temperature; (5) metal composition; and (6) annealing.—*R. E. Thompson.*

Apparatus for the Softening of Water. Schneebeli, J. Swiss P. 132,327; Chem. Zbl., **1929**: 2, 1724. A collecting chamber for sludge, with opening which can be closed, is supplied at foot of water reservoir which has also an easily removable measuring vessel for softening medium and a cock for withdrawing softened water.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board).*

Preparation of Base-Exchange Silicate. Friend, R. O., and Partridge, E. M. (Assrs. to Permutit Co.) U. S. P. 1,720,074; Chem. and Indust., 1929, 48: B. 814. Greensand is treated with sodium silicate and thoroughly washed. Sufficient aluminum sulphate is added to neutralise remaining sodium silicate and render reaction acid.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board*).

Removal of Dissolved Silicic Acids from Liquids, Especially Water for Domestic or Industrial Uses. Rosenheim, A. B.P. 291,435; Chem. and Indust., 1929, 48: B. 798. Filter beds comprising dried gels which can form insoluble or slightly soluble silicic acid adsorption compounds, polysilicic acid compounds, or double silicates, are used. Process is combined with softening by using gels containing alkalis. Regeneration is by treatment with alkalis.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board*).

Treatment of Feed Waters for Boilers, Condensers, etc. Kent, D. W. U. S. P. 1,725,925; Chem. and Indust., 1929, 48: B., 874. Water passing through series of shallow superimposed vessels meets current of hydrogen-containing gas which is not active in scale formation. Bottom of each vessel is formed of porous medium through which gas diffuses. Gas is prepared for recirculation by burning the oxygen with hydrogen and making good any loss.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board*).

Report of the State Bureau for Drinking Water Supplies (Holland) for 1928 (Rijksbureau voor Drinkwatervoorziening). Krul, W. F. J. M. Reprinted from Verslagen en Mededeelingen betreffende de Volksgezondheid, September, 1929. In his report the Director discusses the growing realisation of importance of public water supplies and of importance of co-ordination. He enumerates most important advances in water supply during 1928 and gives brief accounts of developments in the different districts. Aims and methods of the Bureau are described, and account is given of its activities in connection with water supply undertakings and various problems and investigations connected therewith.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board*).

New Researches on the Sterilisation of Drinking Water Supplies. Ottolenghi, D., and Ceredi, A. Igiene mod., 1928, 21: 321; Zbl. ges. Hyg., 1929, 19: 725. An Italian stable chloride of lime preparation "Chlorante" has proved very suitable for sterilisation of drinking water. For pure water, quantities of chlorine under 1 mg. per litre suffice for sterilisation. For waters containing much organic matter chlorine dosage must be higher, from 7.5 to 15 mg. per litre, chlorinous taste being afterwards removed with sodium thiosulphate.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board*).

A Method for the Softening of Water. SANFORD, S. A. U. S. P. 1,705,589; Chim. et Indust., 1929, 22: 497. A product containing barium fluoride will, when added to water, precipitate the bases which cause temporary and permanent hardness, without the addition of coagulant.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board).*

A Process for Increasing the Base-Exchanging Property and Stability of Glauconite or Analogous Products by the Action of Chemicals. ROSENHEIM, A. G.P., 452,147; Chim. et Indust., 1929, 22: 497. Process is characterised by treatment of these substances, preferably at temperature above 70°C., with salt, in alkaline or ammoniacal solutions.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board).*

A Process for the Softening of Water by Base-Exchange. MORAWE, K. G.P. 460,743; Chim. et Indust., 1929, 22: 497. Process consists of filtration through layer of lignite. After softening action has ceased, lignite is regenerated by treating it with solution of an alkali salt such as common salt.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board).*

Silicic Acid Content and Boiler Feed Water. BLOK, C. J. Pharmac. Tijdschr. Nederl.- Indië, 6: 273; Chem. Zbl., 1929, 2: 1955. A soft water from west coast of Sumatra with 0.052 gms. SiO_2 per litre, when used without treatment for steam raising, caused a deposit of scale 2 mm. thick. This was prevented and deposited scale slowly redissolved by treatment with from 3 to 4 cc. 0.1 N Na_2CO_3 per 100 cc. SiO_2 content of dry residue of boiler water was at most 3 per cent. Free colloidal SiO_2 also attacked boiler parts at temperatures of 150–200°C. SiO_2 can best be determined by WINKLER's method.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board).*

Process for the Improvement of Brewery Water. JALOWETZ, E. G.P., 466,508; addition to G.P. 465,813; Chim. et Indust., 1929, 22: 497. In waters which contain significant quantities of alkaline sulphate in presence of carbonate, definite relationship may be established between carbonate and alkaline sulphate content, either by adding gypsum to increase sulphate hardness, or lime, to decrease that due to carbonates.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board).*

Water Softening for the Textile Industry. O'Callaghan, J. P. Text. Merc., 1929, 80: 64; J. Textile Inst., 1929, 20: 512. Different types of water-softening plants at present in use, e.g., lime-soda and base-exchange processes, are described. A dual process is now employed in cases where water supply contains large proportion of alkaline earth carbonates, softening being completed by Permutit treatment after filtration through sand.—*M. H. Coblentz (Cour-*

tesy of the Department of Scientific and Industrial Research, Water Pollution Research Board).

London Water Supply. A Year's Work Reviewed: Serving a Population of Seven and a Half Millions. Surveyor, 1929, 76: 482. Condensed from review by STRINGER, G. F., of work of Metropolitan Water Board during year ended March 31, 1929. Data are given of quantities of water supplied, of increase in water supplied and in population, and of storage and subsidence reservoir capacity for unfiltered water at end of year. Liability for maintenance of pipes under streets, requirements of Board with regard to domestic apparatus, emergency measures occasioned by frost, and Holborn explosion are discussed. Increases in equipment of waterworks since 1904 are shown in a table.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board).*

Chlorine Demand and Bactericidal Effect of Chlorine in the Sterilization of Drinking Water. FROBOESE, V. Gesund. Ing., 1929, 52: 791. Author discusses methods used by different workers for estimating condition of a water and sterilising effect of chlorine by chlorine-demand, chlorine-capacity, and chlorine-number and connection between oxidizability (potassium permanganate demand) and chlorine-number. Conclusion reached by some workers that disinfectant action is confined to free chlorine (i.e., that chlorine which is present in water as dissolved gas) and that "separable" chlorine (i.e., that chlorine which is freed by acidification) has little effect, led author to carry out several series of experiments on the effect of chlorine with river water and with tap water to which sewage after settling had been added. Tables of results of these experiments are given. Disinfecting action of chlorine was much stronger in tap water, even when much less chlorine was used. It appears that when water containing humus matter is treated with chlorine, chlorine goes partly into permanent combination as chloride and partly into combination as "separable" chlorine which, even when separated by acid, has little disinfectant action. With waters containing only domestic sewage, chlorine disappears more slowly and disinfectant action continues longer; apparently compounds are formed which continuously decompose and supplement action of the "free" chlorine. Estimations of excess chlorine with and without acidification therefore give an insight into the progress of chlorination of water.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board).*

Oligodynamic Sterilisation of Drinking Water by the Katadyn Process. KONRICH, F. Gesund. Ing., 1929, 52: 804. Author discusses first, discovery of oligodynamic action of metals and metal salts and investigations of different workers into process, which appears to be probably of chemical nature, due possibly to metallic ions, not in themselves, but as oxygen carriers. Effect varies with different bacteria and can be weakened or increased by additions of different substances. Theory of action on living cells is discussed and table is given summarising results obtained by different investigators. KRAUSE'S Katadyn silver, which is prepared by a blasting process, or by precipitation on

sand or porcelain, and tests therewith are described. An illustration shows effect on solid nutrient medium. In contact with liquid medium, bactericidal action of Katadyn sand was considerably more rapid and effective than that of other oligodynamic agents. Action increased with increased quantities of sand and time factor was also of importance. Tests with water which had been in contact with Katadyn sand showed that it had attained very considerable bactericidal strength. Slight differences in method of precipitation of silver, or in material upon which it is precipitated, may cause decided differences in activity and different coli groups show different resistances. Actual contact of all the water with the sand is of importance, as effect does not travel far in water which is not in actual contact. Influence of temperature between 0° and 20° is considerable, but between 20° and 37° there is no marked effect. Pathogenic bacteria show little variation in their resistance. No difference was found in effect of sand after being in use for 3½ months. Possible damage to health from dissolved silver is considered and conclusion reached, that it may be disregarded. Investigation of prevention by this process of growing of bacteria through a filter is in progress. Work of other investigators is discussed and references to literature are given.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board*).

Softening of Water and Removing Iron and Manganese Therefrom by Base-Interchange, and Preparing the Requisite Agent Therefor. Rosenheim, A. B. P. 286,307; Chem. and Indust., 1929, **48**: B. 962. Material with which water is brought into contact is formed of metal oxide gel, or silica gel, or mixture of these, in which alkali oxides or metals, or ammonium ions, have been incorporated. For purpose of incorporation, gels are treated with aqueous solutions of (1) caustic alkalis and ammonia, (2) alkaline reacting alkali-metal or ammonium compounds, or (3) basic reacting substances the cations of which are not those of an alkali metal or ammonium, with subsequent treatment by a solution of an alkali compound.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board*).

A Continuous Circulator for Corrosion Examination or for Continuous Filtration. Brown, J. M. D. Chemist-Analyst, **18**: 16; Chem. Zbl., 1929, **11**: 2226. Description of easily constructed apparatus, without pump, which with an aspirator and constant water pressure will draw a heated liquid through a corrosion bath for an unlimited time and can also be adapted for continuous filtration.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board*).

The Prevention of Boiler-Scale Formation. Alsberg, J., Assr. to Superheater Co., N. Y. U. S. P. 1,717,905; Chem. Zbl., 1929, 11, 2234. Addition of protective colloid, such as tannin-containing substance extracted from bark of various trees, to cold water prevents formation of boiler scale while boiler feed water is being heated before reaching the steam boiler—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board*).

The Purification of Swimming Pools. Modern Methods Employed at Hammersmith, London, Eng. Munic. Eng., San. Rec., and Munic. Motor, 1929, **84**: 680. Open-air swimming pool at Bloemfontein Road, Hammersmith, has capacity of 370,000 Imp. gallons. Water-purifying plant includes cast-iron strainer box, with removable strainer, shunt feed apparatus for coagulant treatment with aluminoferric and ammonia, four 8-foot 6-inch diameter pressure sand filters, cleaned with compressed air, electrically driven circulating pumps, manometer type "chloronome" for accurate addition of chlorine gas, about 1 part per 2,000,000, and electrically driven centrifugal pump. Small rotary compressor supplies compressed air to enclosed type aërator through which air and water pass upwards together in contact. Circulating water is removed from deep end and returned after purification at shallow end through three inlets, each fitted with valve. Movement is imperceptible to bathers. Contents of the bath are completely circulated every six hours at rate of 60,000 gallons per hour. Same water can be used for whole season and still remain absolutely clear and sparkling and free from obnoxious bacteria. History and detailed description of open-air pool are given. *M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board*).

Water Supply as a Factor in Town and Regional Planning. PEPLER, G. L. J. Inst. Munic. and County Eng., 1930, **56**: 911. Author emphasises importance of collaboration between town planner and water engineer and refers to memorandum issued by Ministry of Health in 1928 in which establishment of Regional Water Committees is advocated. Preservation of catchment areas from pollution, question of public access to such areas, river side development, disposal of mine waters in a chalk area, and other matters in which regional planning may assist the safeguarding of sources of supply are discussed, and reports of Manchester and District and of Bath and Bristol Region Joint Town Planning Committees are briefly referred to. Planning of town development with view to economy in water engineering is also discussed. In discussion, questions of public access to reservoirs and catchment areas, water supply in small and scattered communities, and laying of mains under roads, were brought forward.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board*).

Problems of the Supply, Preparation and Utilization of Water. KÜHNE, K. Das Berliner Heft, Kl. Mitt. Ver. f. Wasser-, Boden-, u. Lufthyg., 1930, Supplement 6, 27. First problem in water supply is quantity and this is leading often to choice of surface supply capable of treatment and with assured future, in preference to ground supply of better quality. Effects of artificial ground and slow sand filtration are compared, and technical difficulties of supplies of different types are described. Ground water from deep wells presents greatest difficulty. Amount required for a modern supply and its probable increase and prevention of waste are discussed, and author gives brief survey of purification methods, dividing them into treatment for domestic and for industrial use.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board*).

Poisoning by Drinking Water. KATHE. Zbl. ges. Hyg., 1929, **20**: 259; Wass. u. Abwass., 1929, **26**: 260. Author describes cases of lead poisoning which were only correctly diagnosed when analysis of water supply had shown it to contain 6.3 mg. lead per litre. Cases of chronic arsenic poisoning were caused by a water supply from wells fed from valleys in which were large deposits of slag containing arsenic.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board*).

Separation of Sea Water into Fresh Water and Salt Solution. MALCOR, M. M. G. F.P. 34,967; Chem. Zbl., 1930, 1, 273. Addition to F.P. 630,533 (see W. P. R. Summary, 1930, 3, Abst. No. 519). Sea water is cooled to freezing point and brought into contact with frozen soft water. Grains of soft-water ice separate from the sea water and brine settles to bottom of vessel. Diagram of apparatus is given.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board*).

Sheffield Water Supply: New Works in the Ewden Valley. Engineer, 1930, **149**: 124. Illustrated description of construction of More Hall and Broomhead reservoirs in Ewden Valley and works associated with them. History of proposal to construct these reservoirs, which were brought into use in October of 1929, is given. Associated works include battery of 32 pressure filters at Broomhead reservoir and storage reservoir at Wadsley. Plan and detailed description are given of valve shaft at Broomhead reservoir, which allows for draw-off of water from two levels and its supply from either level to tunnel leading to More Hall reservoir, or to filters, or to both simultaneously.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board*).

The Water Supply of the City of Lyons, France: Verdunisation of Water at Lyons. C. P. Le Génie Civil, 1930, **96**: 40. Full account of system installed for application of Eau de Javel (hypochlorite) to water of Lyons, as precautionary measure after outbreak of typhoid in suburb served from another supply. Apparatus follows BUNAU-VARILLA plan, except that final filtration is through sand instead of through cotton.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board*).

Method and Apparatus for Water Purification. HÜLSMEYER, C. U. S. P. 1,683,780; Chem. Zbl., 1929, **100**: 684; Wass. u. Abwass., 1929, **26**: 177. Deoxidising agents such as magnetic oxide of iron, iron hammer scale, etc., can be used in finely divided state for water purification and recovered by magnets from discharged water. Water is purified from air, gases, and mineral substances by spraying it, with oxide or iron, through fine nozzles in a cylindrical tube. Further purification is effected by filter beds of steel borings, etc., arranged on perforated plates in upper part of purifier.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board*).

Purification of Swamp and Moorland Water. BREDE, R. F. P. 665,964; Chem. Zbl., 1930: 1, 273. Waters which contain colloidal impurities, humic acids, and organic salts of iron and manganese are treated with dilute acid (for example, $\frac{N}{100}$ hydrochloric acid) and stirred for 10 minutes. Dilute solution of aluminium sulphate is then added with further stirring. Colouring matter and other impurities are precipitated and removed by filtration through filter cloth which is coated with precipitated aluminium hydroxide.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board*).

Filtration. I. BOZZA, G., and SECCHI, I. Giorn. Chim. Ind. Appl., 1929, 11: 443 and 487; Chem. and Indust., 1930, 49: B. 85. Results of experiments on filtration of water, calcium chloride solutions, alcohol, benzene, petroleum, and petroleum-oil mixtures through beds of quartz and galena particles of different sizes indicate that: (1) DARCY'S law is generally obeyed except in case of very fine and non-homogeneous galena under rather high pressure-gradients; (2) filtration constants found with washed and very homogeneous quartz agree with those given by KING and SLICHTER, but not with those calculated either according to EMERSLEBEN'S theory, or on the hypothesis that filter may be regarded as a number of capillary tubes; (3) provided filter is the same, liquid of high surface tension filters more readily than one of low surface tension: thus specific characteristics of solid and liquid exert considerable influence, which is probably related to the inter-surface tension between them.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board*).

The Theory of the Chlorination of Water. ROKITA, W. Brauer-Hopfen-Ztg. Gambrinus, 1929, 56: 346; Chem. Zbl., 1930: 1, 1193. Author gives abstract of article by WOJTKIEWICZ, MISCHUSTIN and RUNOW (Cbl. Bakt., Parasitenk., 1929, 77: 21), with information on work of Austrian Experimental Station for Fermentation Industry (Österreiche Versuchsstation für Gärungsgewerbe). Free chlorine is detected by α-naphthoflavone and $\frac{N}{50}$ thiosulphate solution.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board*).

Dechlorination of Water by Activated Carbon. PICK, H. Vom Wasser, Ver. deutscher Chemiker, Berlin, 1929, 3: 71. Author describes series of experiments carried out to obtain practical knowledge of working of activated carbon filter for dechlorination of superchlorinated water. First series of experiments described were of short duration, carried out with fresh filter material. It was found that percentage decrease in chlorine content for given length of filter and given speed of flow was independent of original concentration of chlorine. Increased speed necessitated increased length of filter. Different activated carbons (AKT II, III, and IV, and Urbain NAS 18) are classified by length of filter required to reduce chlorine content of water by one-half at speed of 1 cm. per second (24 inches per minute) and method of calculating

size of filter required is described. In further experiments continuing over a considerable time it was found that life of filter material without regeneration varied with composition of water. Regeneration investigations showed that treatment of carbon either with hot soda solution in filter, or by removing from filter and heating to dull redness was successful. "Fatigue" in filter appeared to be due to formation of gelatinous membrane which was peptized by hot alkali, or destroyed by heating. With hard carbons, loss of material in regeneration should not be serious. Experiments on practical scale in superchlorination and dechlorination were made with portable "Dabeg" plant to determine possibility of using Elbe water for Aussig supply, and on the very favourable results decision to use Elbe water as supplementary supply was based. In course of discussion author stated that his calculations of size of filter required held good for most natural waters, but the presence of ammonia, owing to formation of chloramine, lengthened time necessary for dechlorination. BACH described experiments with activated carbon on which he based conclusion that it was useful for water treatment on small scale, but that its economical application in water works was uncertain. SIERP stated that regeneration was satisfactory if loose filter film was first washed off and then superheated steam used. He described a large-scale filter erected by the Ruhrverband. Further experiments showed possibility of complete removal of phenol from raw ammonia water by activated carbon. HELLER described treatment of Magdeburg water and difficulties experienced with corrosion in the filters. BRUNS dealt with small tap-filters for household use. *M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board).*

Explanation of Oligodynamic Action. FREUNDLICH, H., and SÖLLNER, K. Biochem. Z., 1928, 203: 3; Kolloid Z., 1930, 50: 181. Amount of silver dissolved from plane surface by water can be estimated by HABER's method. Algae appear to absorb this silver, which destroys them. Silver nitrate in solution also shows oligodynamic action, which must be ascribed to silver ions in solution. In water, silver apparently goes into solution under influence of oxygen and carbon dioxide. In a glass vessel, silver is adsorbed by glass walls and may be dissolved by addition of fresh water. This accounts for oligodynamic action exerted by glass vessels that have been in contact with silver, even after rinsing with water.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board).*

Oligodynamic Action: Action of Metallic Ions. LEITNER, N. Klin. Wochenschrift, 1929: 8, 1952; Chem. Zbl., 1930: 1, 252. Oligodynamic action of metals and of metal salts is due to metallic ions which go into solution; equal ion-concentrations have equal effect, whether ions are from metals or from salts. In general, pure metals are used; but have the disadvantages of rapid exhaustion and depositions on their surface.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board).*

The Katadyn Process of Water Sterilization. SCHWEIZER, C. Mitt. Lebensmittelunters. Hyg., 1929, 20: 303; Chem. Zbl., 1930: 1, 1513. Katadyn steri-

lisers, which are for use with water only, effect destruction of pathogenic and coli bacteria, while no diminution is observed in numbers of harmless bacteria present.—*M. H. Coblentz (Courtesy of the Department oj Scientific and Industrial Research, Water Pollution Research Board).*

The Purification of River Water for Domestic Supply by Means of Lime. NICOLAI, A., and BLOMMENDAAL, I. H. N. Geneesk. Tijdschr. Nederl.-Indië, 1929, **69**: 879; Zbl. ges. Hyg., 1930, **21**: 501. Description of plant for simultaneous precipitation and disinfection of small supply of tropical river water by lime, treating 5 cubic meters [1300 gallons] per hour. By branch pipe controlled by a cock, a stream of water from main is directed through lime tank, and with lime in strong concentration, rejoins main flow in mixing tank. Mixture passes through two settling tanks to sand filter, which is renewed after about 1,000 cubic meters have passed. Residual calcium hydroxide is converted to calcium carbonate in neutralization tank and allowed to settle in settling tank. Resulting water contains 11.2 mg. per litre of lime, has low bacterial content, and is suitable for domestic and industrial use.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board).*

Method for Purifying and Softening Water. Western Boiler Compound and Chemical Company. Ass. to FRISCHER, M. L. U. S. P. 1,722,137; Chem. Zbl., 1930: 1, 1194. Agent is aqueous solution of NaF, $Al(OH)_3$ and a softening agent. NaF is added in such quantity that aluminium hydroxide is dissolved and no precipitation of aluminium compounds takes place. To 10 parts of $Al(OH)_3$ are added 5 parts NaOH, 7 parts KOH, 5.5 parts NaF, 16 parts Na_3PO_4, and 20 parts $Ba(OH)_2$.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board).*

Process for the Operation of Base Exchange Filters. MORAWE, K. G. P. 488,078; Chem. Zbl., 1930: 1, 1019. Loosening of base exchange material in filter is accomplished by several successive pumpings through filter material of salt-containing water previously used for regeneration. A plan illustrates process.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board).*

Base Exchange Material. BEHRMAN, A. S. (to the Permutit Co.). U. S. P. 1,736,281; Chem. Abst., 1930, **24**: 674. About 31 mols. sodium silicate and from 8 to 10 mols. basic aluminium sulphate are mixed in solution, concentration being such that gel forms on mixing. Product is leached and is suitable for softening water.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board).*

Stabilizing and Improving the Base-Exchanging Properties of Silicates. ROSENHEIM, A. B. P. 302,690; Chem. and Indust., 1930, **49**: B. 103. Solutions of acid-reacting salts of metals which are at least bivalent, but preferably tervalent and amphoteric, solutions of alkali salts having an alkaline reaction, and neutral alkali salt solution are used successively to treat glauconite, or

material containing or resembling it, at the ordinary temperature. First two treatments may be repeated alternately until treated material, which may be washed with water between treatments, produces no turbidity in water to be softened.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board*).

Studies of Brewing Waters. LÜERS, H. Chem. Ztg., 1929, 53: 998. Results of experiments on removal of carbonate from brewing water and effect on color and taste of light beer are discussed. Carbonate was removed by boiling, by softening with lime in the cold, by softening with lime and adding gypsum, and by neutralising with acids, similar materials and brewing processes being used in all cases. More carbonate was removed and a better-tasting brew was obtained by softening with lime than by softening and treating with gypsum. Softening also increased nitrogen and phosphoric acid contents of wort. Lactic acid treatment completely removed carbonate hardness and gave a mild, good-tasting beer, but necessitated larger dose of hops.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board*).

Boiler Feed Waters. BUTLER, F. W. W. J. South African Chem. Inst., 1930, 13: 7. General survey of requirements, and of methods of preparation of boiler feed water. After referring to acid and electro-chemical theories of corrosion, author describes corrosive effects of different constituents of natural waters and, taking Durban water works as an example, general treatment of a water supply. Article describes effects of gases, processes of de-aëration and and de-activation, softening by lime-soda, lime-barium, and zeolite processes, use of evaporators, and internal treatment by boiler compounds. In conclusion, author points out advantage of controlled system, especially continuous system, of blow-down, and importance of routine tests, especially of hydrogen ion concentration.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board*).

Process and Apparatus for the Supply of Boiler Feed Water, Especially for High-Pressure Boilers. BÜHRING, O. F. P. 667,620; Chem. Zbl., 1930: 1, 273. Sodium carbonate, sodium hydroxide, or potassium hydroxide, is used as purifying agent, and water, in presence of excess of purifying agent, is heated under pressure so that simultaneous chemical and thermal purification takes place. Sludge withdrawn from this part of process is added to next charge of water before treatment. Apparatus and process are shown in diagram.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board*).

Water-Softening Plant on the Great Southern Railways of Ireland. Engineer, 1930, 149: 103. Four water-softening plants of Lassen-Hjort continuous automatic separate measurement type have been installed by Great Southern Railway of Ireland at principal points on main line. Drawings and description are given of plant at Inchicore Locomotive Works, near Dublin.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board*).

The Sterilization of Sea Water by Means of Chlorine. Wood, D. R., and Illing, E. T. Analyst, 1930, 55: 125. Description is given of investigation made in connection with proposal to chlorinate water of a sea-water swimming pool. Effect of bromine, produced from bromides present in sea water by displacement of bromine by chlorine, on taste, its irritant effect, and its sterilizing action were examined. Tests were made by brominating fresh water, as this has same net result as chlorinating sea water, but enables taste to be judged more readily. Experiments showed that bromine is as efficient for sterilization as is its equivalent of chlorine, and is not perceptibly more objectionable as regards taste and effect on the eyes.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board*).

Methods of Chlorination at Small Water Works to Handle Population Peaks. J. H. Miller. The American City, 44: 6, 107, June, 1931. At Beulah Beach, Ohio, where normal population of 100 rises annually to 5,000 for a short period, sterilization difficulty had been adequately met. Maximum pumpage is 25,000 gallons per day and average, 6,000. Use of HTH has proved satisfactory. Requisite quantity is dissolved in a barrel of water and applied by means of drip feed at entry to clear well. Operators are trained to regulate the drip feed and check chlorine residual. Cost has been $4.77 per million gallons, making daily cost almost negligible.—*Arthur P. Miller*.

Active Carbons for the Purification of Drinking Waters. J. C. Liddle. Water and Water Engineering, 33: 390, 261–263, June 20, 1931 and 392, 380–382, July 20, 1931. General review of subject, instancing successes of various plants in giving fresh pleasant taste to water containing either dissolved organic matter, or free chlorine. River Ruhr water is chlorinated and filtered upwards through bed of granular active carbon which is cleaned monthly by counter-flushing, steamed occasionally, and must be reactivated, or renewed, every 15 months. Filter at Dresden to handle 10,000 cubic meters (about 2.6 million U. S. gallons) has carbon bed 2.5 meters deep which removes undesirable flavor from river Elbe water; no steaming, or flushing, has been necessary after 6 months work. At Magdeburg, powdered carbon fed on to slow filters to depth of less than one millimetre offers great resistance to filtration, but at Southend, England, powdered carbon stirred into the water prior to filtration has given consistently satisactory results throughout 8 months operation. Superchlorination and subsequent filtration through carbon is dealt with and Aussig plant, which thus treats subsoil water from borings along the side of the Elbe, is described. Water enters carbon filters with from 1 to 1.5 parts per million free chlorine and is filtered downwards through 2.6 meters of granular carbon. After 11 months working filter has not needed regeneration. A larger plant (40,000 to 60,000 cubic meters, from 10 to 15 m.g., U. S., daily) installed at Stuttgart in 1930 is treating Neckar water, the carbon dechlorinating, improving color, and reducing organic matter. Inclusive cost of carbon treatment at Stuttgart is about 0.3 pfennig per cubic meter, or about 0.32 cents per 1000 gallons, allowing 20 percent depreciation, interest on capital, extra pumping, and carbon regeneration and replacement. At Hamm, total cost

is about 0.45 to 0.50 pfennig per cubic meter, or approximately 0.5 cents per 1000 gallons. [Cf. Chlorinated drinking water, THIS JOURNAL, 23: 7, 1078–1079, July, 1931.—ABSTR.]—*W. G. Carey.*

Water Shortage in Jerusalem. Anon. Water and Water Engineering, 33: 390, 267, June 20, 1931. Serious shortage is expected and water is to be supplied to consumers once in three days instead of daily; municipality is also arranging to have water brought by train from Ludd, two hours journey away. —*W. G. Carey.*

Corrosion of Iron and Steel. Anon. Water and Water Engineering, 33: 390, 269–270, June 20, 1931. Corrosion committee of Iron and Steel Institute summarize in their first report answers to questionnaire sent to producers and consumers of iron and steel. General opinion is that protective coating, if skilfully applied, amply repays its cost. Small differences in composition of metal affects corrosion, e.g., small amount of copper added increases resistance to corrosion. For covering buildings, galvanizing is necessary and wrought iron sheet, rather than mild steel, is recommended. Under special conditions, particularly on certain alloy steels, film of oxide may be sufficiently uniform to render metal passive against corrosion; but film on ordinary steels is generally not uniform and corrosion occurs in thin places owing to electro-chemical action between metal and oxide film. Amongst problems which committee intends to investigate is that of water treatment with view to preventing corrosion.—*W. G. Carey.*

The Distribution of Goiter in Hungary and its Relation to the Iodine Content of Drinking Waters. J. STRAUB. Ztschr. f. Hyg. u. Infektionskr. 1930, 111: 472–9. From Bulletion of Hygiene, 6: 5, 424, May, 1931. In Hungary, the drinking water of the plains comes from artesian and deep wells generally and contains about thirty-five times as much iodine as the shallow well and spring water of the mountains. The people of the plains are virtually free of endemic goiter while in the mountains a large percentage of the people in certain districts are afflicted with it. Amount of iodine, however, was not less in waters of goitrous, than in those of non-goitrous, mountain regions. Experiments to determine iodine-content in foods consumed are to be made.—*Arthur P. Miller.*

Report of the Water Pollution Research Board, England, for the Year ended 30th June, 1930, with Report of the Director of Water Pollution Research. R. ROBERTSON and H. T. CALVERT. Dept. Scient. and Indus. Res., London. From Bulletin of Hygiene, 6: 5, 432, May, 1931. Work is being continued on survey of River Tees and on treatment of sugar beet wastes; further studies are being made on zeolite process and on activated sludge process of sewage disposal; and investigation of treatment of corrosive and plumbosolvent waters has been started.—*Arthur P. Miller.*

First Report of the Scottish Advisory Committee on Rivers Pollution Prevention. I. Summary of the Law relating to Rivers Pollution Prevention.

II. The River Tweed and Its Tributaries. Department of Health for Scotland. W. E. Whyte: Edinburgh.—*Arthur P. Miller.*

Sewage and River Purification Experiences. IMHOFF. Surveyor, 1931, 79: 57–8. From Bulletin of Hygiene, 6: 5, 433, May, 1931. To ease present burden on sewage treatment plants, self-purification is being increased by creation of artificial lakes. In this way flow time, or detention period, is increased, thus permitting greater sedimentation. Testing of Ruhr water showed oxygen content at worst places to be about 3.5 mgm. per liter. At mouth of Ruhr, oxygen content again reaches saturation. Length of Ruhr represents at present flow time of about four days. New lakes will increase this time to fifteen days.—*Arthur P. Miller.*

A Study of the Bactericidal Action of Ultra-Violet Light. I. The Reaction to Monochromatic Radiations. J. General Physiol., 1929, 13: 231–48; **II. The Effect of Various Environmental Factors and Conditions.** Ibid., 249–60; **III. The Absorption of Ultra-Violet Light by Bacteria.** Ibid., 1930, 14: 31–42. F. L. GATES. From Bulletin of Hygiene, 6: 5, 444–445, May, 1931.—*Arthur P. Miller.*

The Prevention of Trouble due to Aquatic Growths in Condenser Systems, with Special Reference to the Destruction of Mussels. Critical Résumé. D. V. ONSLOW. The British Electrical and Allied Industries Research Association, Inc., 1929. London.—*Arthur P. Miller.*

The Interaction of Metals and Foods. I. The Relation of Metals to Potable Fluids; Corrosion. B. BLEYER and J. SCHWAIBOLD. Biochem. Ztschr., 1931, 230: 136–45. From Bulletin of Hygiene, 6: 6, 500–501, June 1931. Rate of corrosion of a metal in contact with a liquid may be determined by measuring amount of electric current passing through circuit in which anode consists of plate of metal under investigation and kathode, of plate of inert metal such as platinum, both plates being immersed in the liquid. In this way, rates of corrosion of metals and alloys commonly used in kitchen utensils were determined. Liquids used were hot and cold water, hot tea, and hot coffee. In most instances corrosion proceeded rapidly while the metal and liquid were making contact, but after a few minutes slowed up very much. Lead showed the greatest rate and zinc next; the remainder were very little affected.—*Arthur P. Miller.*

Troublesome Iron Removed from a New Water Supply. W. B. ROLLINS. The American City, 45: 2, 96–97, August, 1931. Platte City, Missouri, with 558 inhabitants, spent $35,000 for new water supply system including 50-foot gravel-wall-type well in the Platte River bottom, elevated storage tank, and the necessary pipe lines; but the water so obtained contained iron in excess of 40 p.p.m. A small iron removal plant was therefore added, results of which have been satisfactory. Treatment consists of aëration, sedimentation, and filtration.—*Arthur P. Miller.*

Corrosion Rates of Steel and Composition of Corrosion Products Formed in Oxygenated Water as Affected by Velocity. B. E. Roetheli and R. H. Brown. Ind. Eng. Chem., 23: 1010-12, 1931. Laboratory experiments on corrosion rates of steel cylinders rotating with varying speeds were conducted. At low velocity, non-resisting granular magnetic oxide of iron was formed, giving excessive corrosion. At higher velocities, ferric hydroxide was produced, which is resistant to oxygen transfer, and decreased corrosion was noted. At still higher velocities, corrosion again increased, due to erosion of this hydroxide film.—*Edward S. Hopkins.*

Effect of Oxygen Concentration on Corrosion Rates of Steel and Composition of Corrosion Products Formed in Oxygenated Water. G. L. Cox and B. E. Roetheli. Ind. Eng. Chem., 23: 1012-5, 1931. Laboratory measurements of corrosion rate of steel in water containing dissolved oxygen show that, below concentration of 5.5 p.p.m., corrosion rate is proportional to oxygen concentration. Above this value, rate is no longer linear function of oxygen concentration. Presence of ferric hydroxide at high oxygen concentration is due to rapid oxidation of ferrous ions to ferric under these conditions.—*Edward S. Hopkins.*

Jacking a Conduit Through Water and Sand. Anon. Railway Engineering and Maintenance, 27: 9, 801, 1931. Slow orders were avoided and construction savings were effected on Pennsylvania RR. near Hammond, Ind., by jacking 66-inch corrugated iron culvert pipe through 14-foot fill under three four-track main lines in order to provide for 36-inch water main extension. The 66-inch culvert pipe was jacked from both sides of fill simultaneously in accordance with predetermined line and level—*R. C. Bardwell.*

Stock of Pipe Fittings. R. C. Bardwell and J. B. Wesley. Ry. Engr. and Maint., 27: 9, 1931. Amount of desirable emergency stock of pipe fittings for railway water service gangs depends upon local conditions.—*R. C. Bardwell*

Repairing Leaks in Pipe Lines. C. R. Knowles, L. L. Tallyn, and R. J. Southcott. Ry. Engr. and Maint., 27: 9, 812-813, 1931. Leaks should be avoided by proper installation and use of water hammer eliminators. Use of clamps, split sleeves, and special joint stamps have proved convenient for repairs.—*R. C. Bardwell.*

Air Lift Pumping. George L. Davenport Jr., and C. R. Knowles. Railway Engineering and Maintenance, 27: 6, 563-564, 1931. Air-lifts are not recommended for wells less than 100 feet deep and preferably 150 feet. Economy with air-lifts is secured when holes are crooked, or when water contains considerable sand. Value of air-lift increases with depth of well, especially over 300 feet.—*R. C. Bardwell.*

Testing Water Meters. C. R. Knowles and Anon. Railway Engineering and Maintenance, 27: 7, 649-650, 1931. Railway water meters can usually be checked by tank measurements. Where tank measurements are not available, standard test meters are recommended.—*R. C. Bardwell.*

Speeding up Trains with Water Cars. Anon. Railway Age, **91**: 10, 354–356, 1931. The Missouri, Kansas and Texas Ry. has eliminated water stops, resulting in savings in time, train miles, fuel, and boiler repairs, by hauling 6,300- to 15,550-gallon capacity water cars with regular 10,000-gallon engine tanks. Records indicate 67.21 per cent return on investment of $109,988. In addition to transportation economics, larger tank supplies permit selection of better quality boiler water with incident saving in better boiler performance and decreased maintenance.—*R. C. Bardwell.*

Calking Lead Joints. L. L. Tallyn and R. L. Holmes. Railway Engineering and Maintenance, **27**: 5, 475–476, 1931. Air hammer is not recommended for 12-inch, or under. On recent installation of 8-, 10-, and 12-inch cast iron pipe, 37.5 miles long, on Texas and Pacific RR., cement joints were used successfully with no leaks at water pressure of 180 pounds per square inch which required no lead calking.—*R. C. Bardwell.*

Zeolite Plants Effect Economics. Anon. Railway Engineering and Maintenance, **27**: 8, 715–718, 1931. Records of 31 zeolite installations on Southern Pacific Railroad show marked improvement in water treated and large savings in locomotive boiler maintenance and repair. Cost of plants vary from $5,000 to $20,000. Scaling matter removed varies from 7 to 34 grains per gallon. Pitting and corrosion together with general boiler maintenance have been reduced, and period between washouts lengthened. Additional installations are being considered.—*R. C. Bardwell.*

Meeting a Crisis in Water Supply. Anon. Railway Engineering and Maintenance, **27**: 6, 557–558, 1931. Statistics from 16 railways, operating a total of 32,668 miles, indicate that 1930 drought, extending from late 1929 until February 1931 was most severe on record. At 70 out of 1643 stations complete failure occurred and correction steps were necessary at 1020 others. At 16 stations water was hauled and increased size engine tanks saved trouble at others. Increased effect of mineral and organic pollution required special treatment to overcome corrosion, scaling, and foaming.—*R. C. Bardwell.*

Better Water Stations Will Save Money. Anon. Railway Age, **91**: 3, 82–85, 1931. In considering means for securing further economy in operation of American railroads, attention is called to results from modern automatic pumping plants and to adequate provision for treatment. Chart showing results from one railroad indicates annual net saving of over $1,000,000 from 177 lime-soda, soda ash, and sodium aluminate treating plants.—*R. C. Bardwell.*

Sand Trap Clears Water. R. L. Holmes. Railway Engineering and Maintenance, **27**: 9, 805, 1931. Sand in water from wells on Texas Pacific at El Paso, Texas, interferred with satisfactory operation of zeolite water treating plant. Cone-shaped sand trap, which reduced velocity of flow from 2.75 to 0.028 feet per second, eliminated trouble. Detailed diagram is shown.—*R. C. Bardwell.*

Water Supplies Reach Danger Line. Anon. Railway Age, 90: 17, 909–912, 1931. Survey of statistics covering effect of 1930 drought on railway water supplies indicated that Maryland, West Virginia, Virginia, and Kentucky, with rainfall only 56 to 61 per cent of normal, were location of most serious trouble, although long dry season also affected other sections. Low stream flow increased the dissolved solid content, causing increased trouble from corrosion and scaling matter. Emergency measures consisted of hauling water at worst affected points and heavy treatment at others, with incident high costs. Diagram of United States is shown with affected area.—*R. C. Bardwell.*

Lehigh Valley Modernizes Water Facilities. E. J. Cullen. Railway Engineering and Maintenance, 27: 5, 454–456, 1931. General water survey on Lehigh Valley RR. indicated desirability of improving facilities at their Manchester, N. Y., terminal. Three automatic electric centrifugal pumps were installed each capable of furnishing 800,000 gallons daily. Water from Canandaigua Lake, containing 9.5 grains per gallon total hardness, of which 7.5 is carbonate, is treated in 47 x 49 feet steel tank with 12-foot downcomer with lime, soda ash, and sodium aluminate at rate of 68,000 gallons per hour. Sparling meter is used for chemical proportioning. Consistently satisfactory results have been obtained, with hardness below 2.0 grains per gallon.—*R. C. Bardwell.*

Welded Iron Pipe for Detroit Water Works. R. C. Beam. Public Works, 61: 8, 46, 1930. Design of 9,300 feet of 54-inch pipe is unusual, in that pipe was delivered in 40-foot sections. Each section contained four Armco ingot iron plates. Longitudinal seams are butt-welded and circular seams, lap-welded. Such a pipe line is not subject to sudden breaks.—*C. C. Ruchhoft.*

Problems of the Distributing System. William J. Grey. Water Works and Sewerage, 77: 389, 1930. Some of the more important problems to consider in pumping station operation are (1) testing electrically driven pumps, (2) supplying station with service water for use in cooling bearings, laboratory work, etc., (3) testing of filters and valves, (4) preparing for breaks, by having on hand supply of fittings and pipes, (5) quality of water and flushing of dead ends and low points, (6) laying of water mains, and (7) meter testing.—*C. C. Ruchhoft.*

Laying an 8,500-Foot Submarine Pipe Line. Harry V. Fuller. Water Works & Sewage, 77: 331–3, 1930. A 12-inch main 1700 feet long and an 8-inch main 6,800 feet long were laid in Casco Bay from Portland, Me. Dredging was done with orange peel bucket, trench dug being 5 feet deep and about 10 feet wide at top and 5 feet wide at bottom. Approaches to submarine line were laid by ordinary land methods to half-tide point. Two pieces of pipe were joined on deck of lighter and hoisted as unit to pipe-laying chute and then scooted ashore. Successive pieces of pipe were then placed. An average of 85 feet of pipe were placed each day, the whole work requiring 100 days of elapsed time. Total cost on 12-inch line was $18.50 per linear foot and 8-inch line, $10.30 per linear foot.—*C. C. Ruchhoft.*

Tight Joints in Water Pipe Line. G. J. Requardt. Water Works & Sewerage, 77: 344, 1930. City of Frederick, Md., recently installed 18-inch cast-iron bell and spigot pipe 3 miles long. Specifications required maximum leakage of 1.18 cubic feet per minute over the 15,000 feet. Leakage test was made with centrifugal pump and showed the pipe to be well constructed and acceptable.—*C. C. Ruchhoft.*

Bacterial Aftergrowths in Water Distribution Systems. John R. Baylis. Water Works & Sewerage, 77: 335–8, 1930. Many water works have been troubled with bacterial increases in water after it has left purification works. Worst conditions are found in cities where either water was not filtered, or else open reservoirs were comprised in distribution system. An overdose of chlorine has not always been the best solution for prevention of overgrowths. In samples taken of filtered water before leaving a certain filtration plant, it was found that during one month not a single 10-cc. tube showed presence of *B. coli* out of about 250 tubes examined; but laboratory faucet water showed 68 per cent of 10-cc. tubes positive. Growths in reservoir of this town, such as algae, protozoa, and rotifers, furnished food for bacterial growth. Experiments show that bacteria will grow on decaying microorganisms. To avoid bacterial aftergrowths, water should be free from suspended organic matter and from any matter that will form a gelatinous coating on the pipes, such as manganese, or iron; also it should be low in organic compounds that support bacterial growths. If this is not possible, water should contain residual chlorine throughout entire distribution system unless water in reservoir contains sufficient dosage of chlorine or other sterilizing agent. Reservoirs should be closed and water should be filtered.—*C. C. Ruchhoft* (*Courtesy Chem Abst.*).

Winning the Confidence of the Public by Efficient Pool Management. Julian M. Bamberger. Municipal Sanitation, 2: 8, 384, August, 1931. A salt water floating public has been converted to a fresh water swimming public in Salt Lake City through instrumentality of: (1) two modern pools aggregating 1,200,000 gallons of filtered, chlorinated, re-circulating water; (2) publicity and education, using slogan "Swim in Water Fit to Drink;" (3) lengthening normal season two weeks, by heating the water to 78°–80°F with two 100-h.p. coal-fired boilers; (3) automatic alarm filter control; (4) replacement of aluminum sulphate coagulant with ammonia alum, with resulting increase in chlorine residual and decrease in consumption both of chlorine and of copper sulphate and in algae growths; (5) careful supervision.—*R. E. Noble.*

A Retrospection of Chlorination. Part 2. Chlorination of Water. Morris M. Cohn. Municipal Sanitation, 2: 8, 386, August, 1931. *Algae Control* is complex. Treatment with copper sulphate has hitherto been, and often still is, depended upon. Treatment with chlorine, however, is now practical and successful. Although objectionable tastes and orders may occur initially, they soon disappear permanently by persistent treatment. *Coagulation with chlorine compounds.* Ferric chloride and chlorinated copperas have been used successfully for coagulation of certain waters, especially those highly colored.

Swimming pool sanitation. Joint Committee on Bathing Places of A. P. H. A. and Conference of State Sanitary Engineers reports that chlorine addition is today the most satisfactory method of pool disinfection, and recommends chlorine residual of from 0.2 to 0.5 p.p.m. in order to maintain continuously the all-necessary bactericidal efficiency. *Cross-connections* still exist in the industries where impure waters are used for fire protection purposes. Development of chlorinator which automatically protects such systems from pollution marks a forward step in water sanitation. *Drought.* Heavy chlorination of doubtful waters during drought has usually been required by health authorities, to safeguard against possible disease spread. To chlorine's credit must be listed reduction in suffering of communities during periods of aridity. *Other uses of chlorine.* Reports indicate that chlorination of condenser cooling water has inhibited growth of algae and improved condenser performance. Inability of chlorine to destroy pre-existing slime deposits in condensers has been reported. Cessation of troublesome algae has resulted from chlorination of water used in artificial ice plants. Contamination which enters pipe lines during laying, from streets and trenches and from the shoes and wearing apparel of workman, has been successfully eliminated by application of chlorine: heavily chlorinated water is allowed a sufficient contact period in the main which, after flushing out, is sterile and ready for service. *Modes of chlorine application.* (a) *Post-chlorination* has been most desirable as a "factor of safety" treatment. (b) *Pre-chlorination.* Increased pollution of raw waters has imposed dangerously high bacterial loads upon rapid sand filter units. It is recognized that, with pre-chlorination, a satisfactory effluent can be produced from raw water with *B. coli* content more than double that permissible without it. This ability of pre-chlorination to destroy a major portion of the bacteria in the delivered water creates a barrier against plant breakdown which cannot be provided by post-chlorination alone. Other benefits claimed for pre-chlorination are that it (1) improves physical conditions of filtration; e.g., by effecting distinct improvement in coagulation; (2) permits lower dosage of alum; (3) tends to lower pH and aid floc production; (4) appears to inhibit development of microscopic life, thus decreasing frequency of basin cleaning; (5) retards septicization of solids in settling basins; (6) reduces clogging of filters, and mud ball formation and cracking, washing frequency, residual iron and alumina, and color of effluent. Main objections to pre-chlorination appear to be: (1) that, at least theoretically, it must conduce to taste formation because of availability of much organic matter to react with the chlorine; (2) potential danger of upsetting biological action in sand beds; (3) that lower bacterial efficiency apparently results from filtration following pre-chlorination and that germicidal effect of post-chlorination is also reduced. (c) *Double chlorination* means both pre- and post-chlorination. It increases margin of safety. (d) *Super- and de-chlorination* means application of large over-dose and subsequent removal of excess, after suitable contact period for sterilization, by means of sulphur dioxide, sodium bisulphite, sodium thiosulphate, or activated carbon. It is especially advantageous with water of high organic content including algae. (e) *Multiple, split, or progressive chlorination* means application of chlorine and maintenance of residual at several points along the collection, storage, and distribution systems.

Usually employed on waters of relatively high physical and bacterial quality. (f) *Ammonia-chlorine process* means application of ammonia prior to chlorination thus forming chloramines. This process is highly effective for taste prevention. It is characterized by more persistent residuals and greater effectiveness on chlorine-resistant spore-formers, algae, and plankton forms. A serious objection is, that sterilization is slower than with chlorine alone, thus necessitating a longer contact period. *Control of chlorine application* by the *ortho*-tolidin test for residual chlorine is standard procedure. It is simple and therefore adaptable to routine plant operation, large or small scale. Residual chlorine determination and control can also be done automatically by a machine recently developed for the purpose. The A. P. H. A. Committee on Water Supply has stated that "chlorination can take credit for a large part of the striking reduction in typhoid throughout the country."—*R. E. Noble.*

NEW BOOKS

Water Supply Control. CHARLES R. COX. Bulletin of Division of Sanitation, New York State Department of Health, Albany, N. Y., 126 pp., 1930. This unusually comprehensive bulletin covers practically all phases of subject and quite in detail. Following the introduction are given factors influencing water quality. Part I. Protection of water supplies from pollution. Types of supply include (1) ground water, derived from wells, springs, or infiltration galleries; (2) surface water, which may involve watershed protection, care of intake, racks, screens and appurtenances, control of algae and other microscopic organisms, and application of copper sulphate (table given); and (3) treated water. Part II. Operation of water purification plants. (1) General principles: self-purification, chemical precipitation, filtration, chlorination, filtration *versus* chlorination, aëration, iron and manganese removal, and water softening, including re-carbonation and zeolite process. (2) Slow sand filtration: operation of filter beds after scraping, scraping filter beds, and washing sand. (3) Chemical treatment: alum, sodium aluminate, ferrous sulphate, ferric chloride and chlorinated copperas, sulphuric acid, soda ash, lime, calcium hypochlorite (chloride of lime), and liquid chlorine. (4) Mechanical filtration: mixing basins, coagulation basins, and rapid sand filters; with 9 sub-heads under last-named as follow: rate of filtration, rate controllers, loss of head gauges, washing filters, care of sand, specifications for filter sand and gravel, "effective size" and "uniformity coefficient," gravel, and removal of sand and gravel from filters. (5) Calculation of chemical dosage: conversion factors, jar test equipment and procedures for (*a*) turbid, alkaline waters, (*b*) turbid, acid waters, or waters of low alkalinity, (*c*) colored waters, and (*d*) prevention of corrosion. (6) Operation of chlorination plants. (*a*) calcium hypochlorite plants; construction, storage, mixing and dissolving, length of dosing period, strength of solution, cleaning tanks, calculation of dose, and control of application. (*b*) Liquid chlorine plants; preliminary precautions, weighing the chlorine, amount of chlorine to be fed from one cylinder, reserve supply, duplicate apparatus, temperature of apparatus, detecting leaks, repairs, cleaning, application of chlorine gas, or chlorine solution, adjusting the apparatus, methods of control of application, and necessity of controlling

application. (*c*) Tastes due to chlorination: excess of chlorine, phenolic compounds, organic matter, and microörganisms. (*d*) Special chlorination procedures: algae control and chlorination of water mains. Part III. Control. (1) Laboratory control: physical examination and chemical analysis, especially the tests for turbidity, color, odor, alkalinity, acidity, free carbon dioxide, total hardness, and residual chlorine (by *ortho*-tolidine, or starch iodide). (2) Bacteriological examination: nature of bacteria and their significance; methods for determining number of bacteria in water and for ascertaining presence of organisms of colon group; presumptive test; partial confirmation test; complete test, ending with summary; and culture media, including sterilization, incubation, nutrient gelatin, nutrient agar, lactose broth, ENDO agar, and eosin-methylene blue agar. (3) Microscopical examination. (4) Facsimile forms for records of chlorination and filtration plant operation. Appendix I. Hydrogen ion concentration: significance, colorimetric determination, application to (*a*) control of filtration plants, (*b*) coagulation of turbid waters, (*c*) coagulation of colored waters, (*d*) prevention of corrosion, and (*e*) softening. Appendix II. Mineral content of water: hardness and alkalinity. Appendix III. Description and list of laboratory equipment and supplies for small filtration plant. Bulletin includes 16 tables, chart, and diagram.—*R. E. Noble.*

Journal of the Southeastern Section, American Water Works Association. 1: 1, 1931. Water Works Problems. GEORGE H. FENKELL. Pp. 8–13. The problems of operating a water department are classified and discussed as follows; political, business procedure, financial, welfare of employees, and technical. **Administration and Financial Problems at Griffin, Ga.** H. P. POWELL. Pp. 13–18. **Administration and Financial Problems at Macon, Ga.** R. E. FINDLAY. Pp. 18–22. **Administration and Financial Problems At Thomasville, Ga.** D. RHETT PRINGLE. Pp. 22–27. Water works administrative procedures in three Georgia cities. **Plankton and Water Supplies.** HUGH A. WYCKOFF. Pp. 27–35. Discussion of purification plant complications due to plankton growth. Influences of dissolved minerals, organic matter, and bacteria as food supplies. **The Use of Copper Sulfate as an Algaecide.** J. H. MARQUIS. Pp. 35–38. Practical discussion of the use of copper sulfate. **Observations on Tastes and Odors.** A. J. SMALSHAF. Pp. 38–46. Experiences in controlling tastes and odors resulting from both phenolic and non-phenolic substances. **The Ammonia-Chlorine Treatment of Water and Its Development.** J. F. T. BERLINER. Pp. 46–55. Relation between pH and the formation of the three chloramines. Physical, chemical, bactericidal, and algaecidal properties of the chloramines are given. Discussion of use in controlling phenolic tastes and odors. Emphasizes necessity of thoroughly mixing ammonia with water before chlorine is added. Use of *ortho*-tolidine test for chloramines and modified test in presence of nitrites are given. **Economics of the Selection and Operation of Centrifugal Pumps.** ROLAND B. HALL and SAMUEL H. SMITH. Pp. 55–58. Practical discussion of the economical selection of centrifugal pumping units. **Some Ground Water Problems in the Southeastern States.** D. G. THOMPSON. Pp. 58–70. Relation of the physiographic and geologic features to ground water occurrence. Discussion of the hydrostatics of salt

water and fresh water in contact along the sea coasts. Observed lowering of head in deep wells due to excessive pumping rather than to deficient rainfall. **Water Softening.** George Bacon. Pp. 70–75. Outline of the zeolite and lime-soda processes and comparison of costs of the two methods. **Observations on Water Treatment at Atlanta, Ga.** P. L. Weir. Pp. 75–81. Operating results in treating the turbid Chattahoochee River water. Treatment consists of pre-sedimentation, coagulation with alum and lime, settling, filtration, and chlorination. **Stream Pollution and Sewage Treatment Methods.** John M. Henderson. Pp. 81–94. Discussion of stream pollution problems and sewage treatment methods from water works superintendent's viewpoint. *W. H. Weir.*

Les eaux d'Egypte. A. Azadian. Ministère de l'Intérieur. Departement de l'Hygiène Publique. Notes et Rapports des Laboratoires de l'Hygiène Publique. Vols. 2 and 3, 1930. Cairo. Imprimerie Nationale. From Bulletin of Hygiene, **6**: 6, iii, June, 1931.—*Arthur P. Miller.*

An Investigation of the River Lark and the Effect of Beet Sugar Pollution. R. W. Butcher, F. T. K. Pentelow, J. W. A. Woodley. Ministry of Agriculture and Fisheries. Fishery Investigations Ser. 1. Vol. III. No. 3, 1930. From Bulletin of Hygiene, **6**: 6, iii, June, 1931.—*Arthur P. Miller.*

Hydraulics for Engineers. Robert W. Angus. Sir Isaac Pitman and Sons (Canada), Ltd., Toronto, 1931, 304 pp., $5\frac{1}{2}$ by $8\frac{1}{2}$ in., figs. 161, price $3.50. This treatise on hydraulics furnishes the engineering student and practicing engineer with the fundamentals of hydraulics plus additional data amassed by the author during thirty years of experimentation, field practice and teaching. Such a fortunate combination has made it possible for the author to present the subject matter in a simpler mathematical form than is usual in the majority of hydraulic textbooks. Although this procedure is desirable in many ways, it increases, however, the time and work required in the solution of certain problems. The book consists of fifteen chapters and two appendices, grouped into three divisions: (I) Flow of Water in Pipes, Orifices, Weirs and Open Channels, 6 chapters; (II) Hydraulic Turbines and Centrifugal Pumps, 5 chapters; and (III) Non-Uniform Flow, 4 chapters. The discussion of hydrostatics was purposely omitted for brevity, although its application appears in conjunction with other hydraulic phases treated. The reviewer believes its inclusion would have made the book more valuable for reference. Chapters 1, 2 and 3 deal with the development of the fundamental (Bernoulli's) equation, methods of determining pressures, velocities and friction losses in pipe lines. The trends of hydraulic grades for pipe lines and the influence of obstructions and various devices together with their hydraulic losses are clearly presented. The basic formula for solving losses in pipe lines is introduced and followed by the calculations of flows in various piping arrangements, nozzles, hose lines and in the venturi meter. The formula for pipe line losses, referred to above, namely: $h_r = f\frac{l}{d}h_v$ is used in conjunction with a set of curves from Fanning's tables. Results obtained therefrom are used here and

elsewhere in the book. Comparisons with other formulae and comments thereon would have given the reader the advantage of the author's experience and observations and justification for the selection. Chapter 4 reviews the measurements of water by orifices and weirs and briefly discusses the Allen and Gibson methods of measurement. Although splendid references are given for weirs, not sharp crested, the inclusion of such data, even in brief form, would have been helpful. Overflow weirs or spillways of dams play so important a rôle in power and water supply engineering that a comprehensive discussion is desirable in a text book of this kind. Chapters 5 and 6 present data on the flow and design of open channels and introduce basic material used in compiling stream flow records. The discussion of open channels is unusually well done and is supplemented by the solution of problems for the guidance of the reader. The data on permissible, safe and scouring velocity are especially valuable. Chapters 7 and 8 define and describe in much detail the fundamental equations, power, efficiency, speed and discharge of turbines. They also include the various hydraulic losses and a discussion of the draft tube. Chapter 9 deals with the regulation of turbines, conditions of operation and gate construction. A method of comparing the merits of turbines is included in example form. Specific speed is briefly discussed. The relation between model and full-size turbines is reviewed with comparative performance characteristics. A description of some modern large turbine installations is given in Chapter 10, while the advantages, nomenclature, classification, theory and performance characteristics of the centrifugal pump are given in Chapter 11. Remaining chapters, in Part 3, deal with the theory and application of non-uniform flow in regular and irregular open channels, backwater and dropdown curves; the economic size of open channels or canals; the phenomenon of water hammer; surge tanks and unsteady motion in closed pipe lines; and the value and limitations of hydraulic models. Two appendices contain discussions of flow in curved channels, vortex motion and water surface in rotating cylinders. Although briefly presented, the mathematical deductions are interesting. The book is accurately indexed, clearly printed, well captioned and significant subject paragraphs are serially numbered for reference. The author introduces symbols, in many instances, with insufficient description of their meaning. Possibly grouping such symbols in a convenient position, for reference, would have simplified immediate identification. For the benefit of the students, well selected problems follow ten of the chapters. Answers to the majority of these are found following the appendices. The answer to example 9 is found under Chapter 4 but the example does not appear in the chapter.—*J. R. McComas.*